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ROYAL AERONAUTICAL SOCIETY

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Edited for the Council by J. LAURENCE PRITCHARD, Honorary Fellow

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NOTICES

Associate Fellowship Examination

The second examination for Associate Fellowship will take place in the Library on Monday, September 24th (Part I.), and Tuesday, September 25th (Part II.).

Binding Cases for the Journal

The arrangements made for the binding of complete sets of the journal in blue cloth cases with gilt lettering at a charge of 4/6 per volume, including the supply of the case, are still in force. Members who desire to take advantage of this arrangement should forward their sets direct to the Lewes Press, Ltd., High Street, Lewes, at the same time sending a remittance for 4/6 to the Secretary at the Society's offices. A note stating the name and address of the sender should be included in the parcel to the binders. The complete volume will be returned direct to members postage paid.

Opening Meeting

The inaugural meeting of the Fifty-Ninth Session of the Society's lectures will take place on Thursday, October 4th, at 5.30 p.m., at the Royal Society of Arts, 18, John Street, Adelphi, W.C.2, when Mr. A. Ogilvie, C.B.E., who becomes Chairman of Council on October 1st for the 1923-24, will read a paper on "Gliders and Light-Planes."

Advance Proofs

Advance proofs of all lectures of the coming session will be obtainable on payment of 6d. each lecture or 5/- for the series of 13. A complete list of the lectures together with an order form will be found among the advertisement pages.

W. LOCKWOOD MARSH, *Secretary.*

METAL AEROPLANE CONSTRUCTION*

BY PROFESSOR HUGO JUNKERS.

Before entering upon the subject of my lecture I beg to express my feelings of gratitude for the honour and appreciation of my efforts, implied in the invitation to speak on metal aeroplane construction before so eminent and learned a body as the Royal Aeronautical Society.

In consideration of the general political situation I deem myself entitled to attribute to this invitation the deeper meaning of a token of amiable disposition given apart and beyond my person, from nation to nation, and to see in it an effort of renewing the ties of a genuine humanity, which is well aware of the unavoidableness of conflict and fight, but does not know hatred, and desires to extinguish the sad traces of a devastating war by hoisting the flag of peaceful competition.

I beg of you to be convinced, ladies and gentlemen, that I am particularly

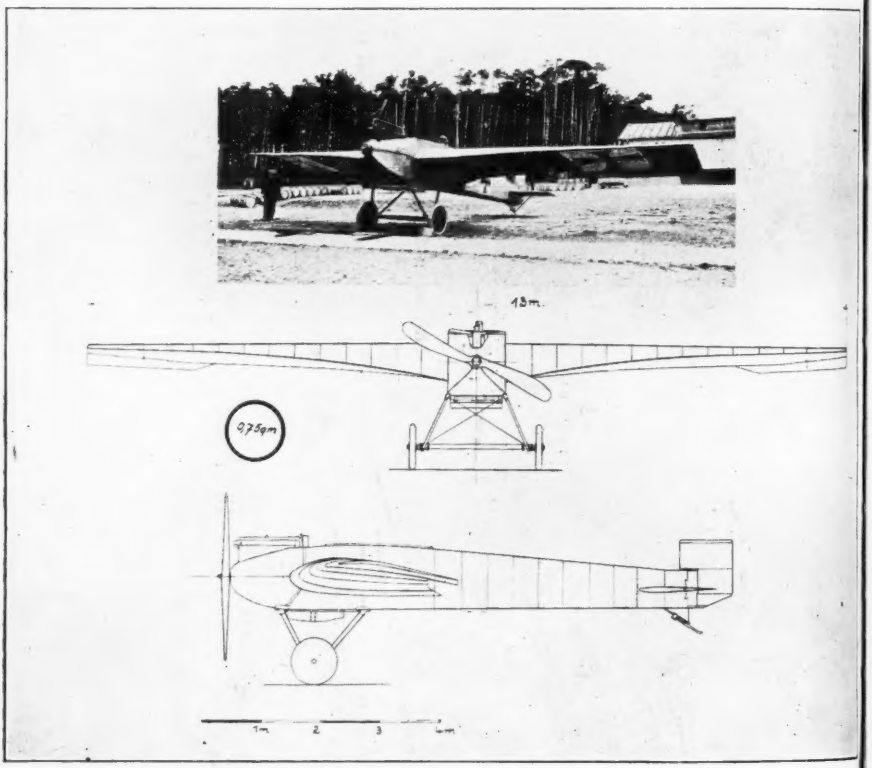

FIG. 1.—*The first iron airplane, J.1 (120 h.p. Mercedes; service weight 1,010 kg.; speed 170 km. (106 E.M.) hour; supporting area = 24 m²).*

* It has been found impossible to obtain Herr Junker's reply to the discussion on the Paper, which is, therefore, printed without comment. Figs. 12, 50, 51, 52 are not printed.—THE EDITOR.

DEUTSCHES REICH

XUM

DEUTSCHES REICH

REICHSPATENTAMT

PATENTSCHRIFT

— № 253788 —

KLASSE 77 *h*. GRUPPE 5.

AUSGEGEBEN DEN 14. NOVEMBER 1912.

HUGO JUNKERS IN AACHEN-FRANKENBURG.

Gleitflieger mit zur Aufnahme von nicht Auftrieb erzeugenden Teilen dienenden Hohlkörpern.

Patentiert im Deutschen Reiche vom 1. Februar 1910 ab.

Fig. 3.

Fig. 1.

Fig. 4.

Fig. 5.

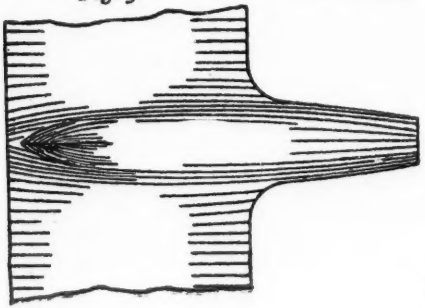

Fig. 2.

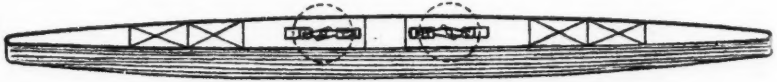

Fig. 6.

FIG. 2.—*Patent.*

sensible to this side of the question and that this appeal has raised a loud echo on our side.

If I have hesitated, however, an instant to respond to your demand, it was to a certain extent due to the feeling of the heavy pressure put upon German air industry in consequence of the war, a pressure which although finding a certain

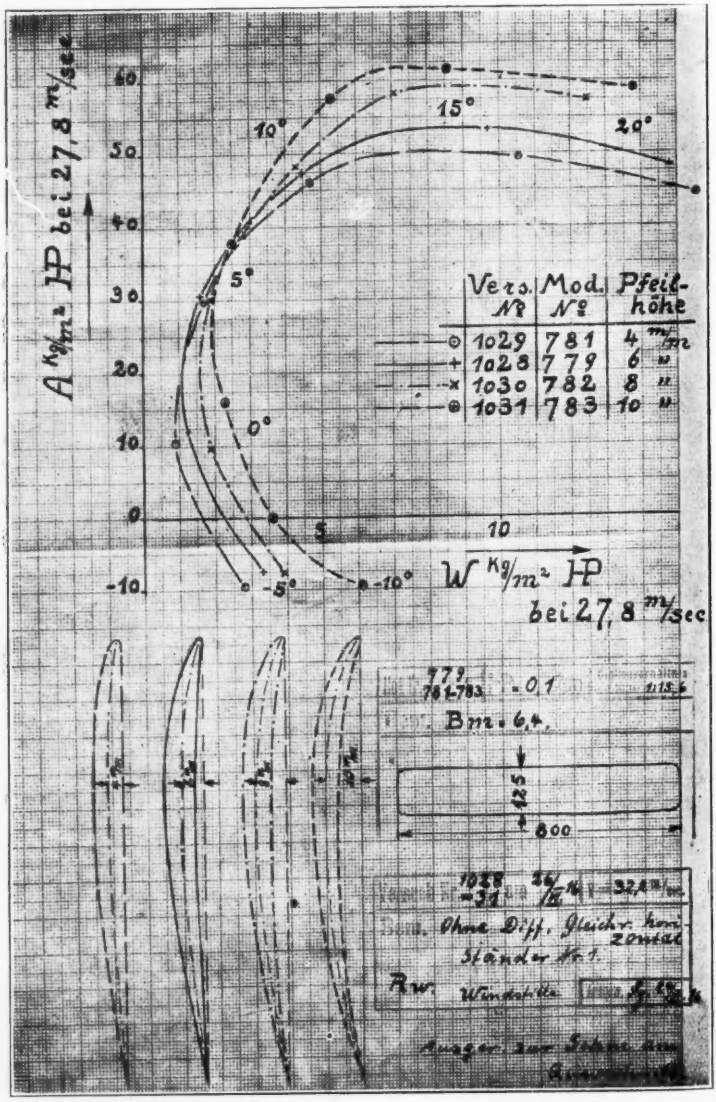

FIG. 3.—*Systematic investigations of wing sections. Effect of the camber of the central line.*

justification as an issue of the war, is nevertheless felt and resented, naturally enough, as a feat of violence overstepping the mark; the acceptance of the invitation possibly then being considered as a sign of acknowledgment of this oppression.

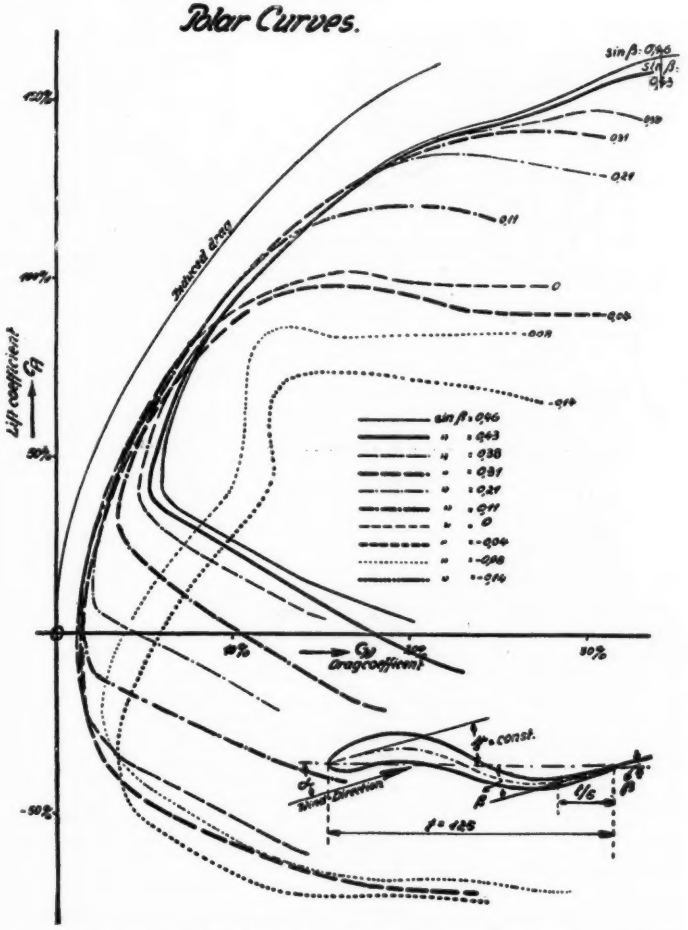

FIG. 4.—*Systematic investigation of wing sections. Tests on the effect of the trailing edge angle β of the central line.*

There had likewise to be taken into account the double-faced sentiment born from a certainly most justifiable instinct of self-preservation; that as on the one side we are not willing to forego our share in the development of aeronautics, we are compelled on the other side, chained by the clauses of the peace treaty, strictly to economise our disposable means, lest we should be defeated in the strife of competition. And not the least, nor worst part of these means is to be found in the results of our investigations, constructions and experiments accomplished under many a hardship.

But all such scruples were wholly suppressed by purely human sentiments and the endeavour to share in the throwing of a bridge over the abyss dividing the nations, a task to the accomplishment of which scientific intercourse is certainly most highly qualified.

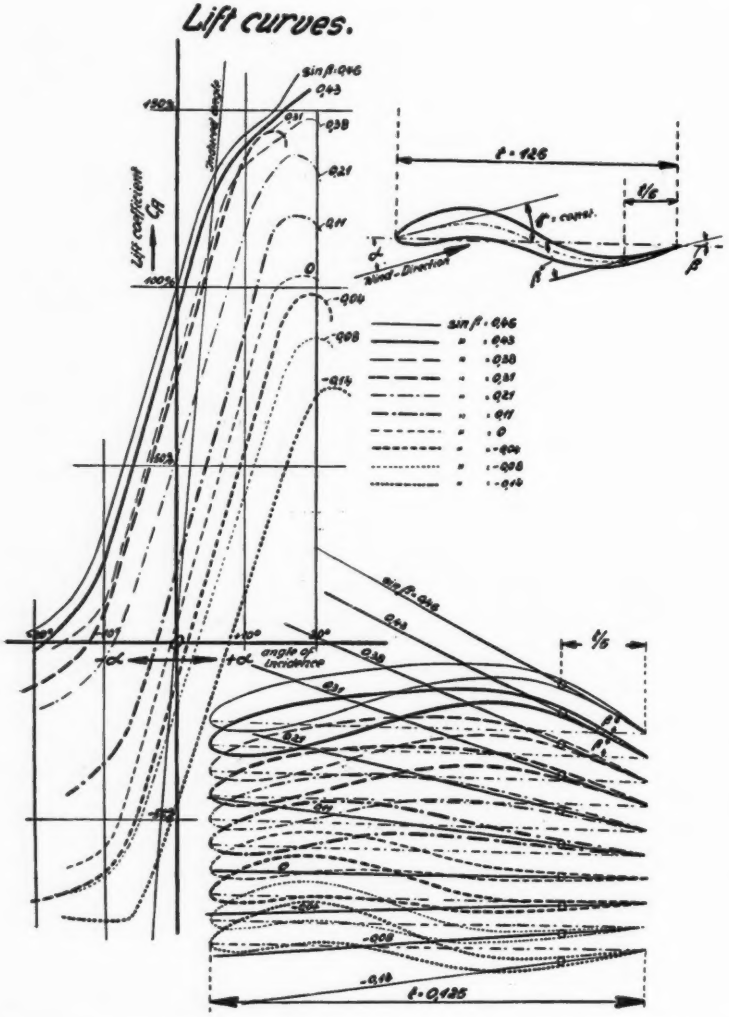

FIG. 5.—*Tests on the effect of the trailing edge angle β of the central line.*

And therefore I have gladly responded to your call and should deem myself very happy if my words meet with a friendly disposition on your side and contribute to the promotion of the agreeable personal connections I was so glad to enjoy in England before the war.

Belonging to the industrial world and consequently obliged to sacrifice all my time and all my efforts to the pursuits of my business, I must forego endeavouring to give you a complete relation of the actual state of metal aeroplane construction from a general standpoint and am compelled to confine myself, with your permission, to sketching an outline of my own work in this technical province.

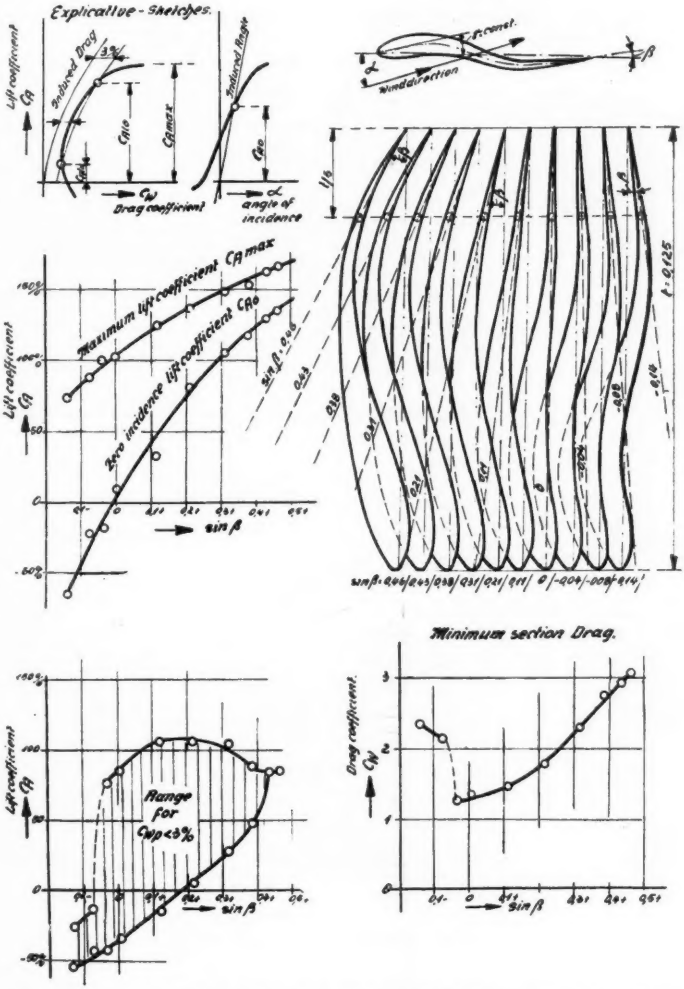

FIG. 6.—*Tests on the effect of the trailing edge angle β of the central line.*

I do not think it would meet with your approbation if I should confine myself to giving a description of my metal aeroplane as *an ultimate and completed product*. The clue to a thorough understanding and full appreciation of the finished article lies in its development; therefore I propose to put in the foreground of my contemplations the evolution of my metal plane and the method

of proceeding and working chosen by me, owing to which I succeeded in the realisation of some new fundamental ideas.

When an innovation is to be carried out in technical matters, the inventive idea represents but a small portion of the work leading to the final product. It will never suffice to carry out the conception with the means by chance at hand, *e.g.*, the working it out in a model. It is necessary to submit the laws of aerodynamics and resistance, the structural shaping, materials, adaptation of

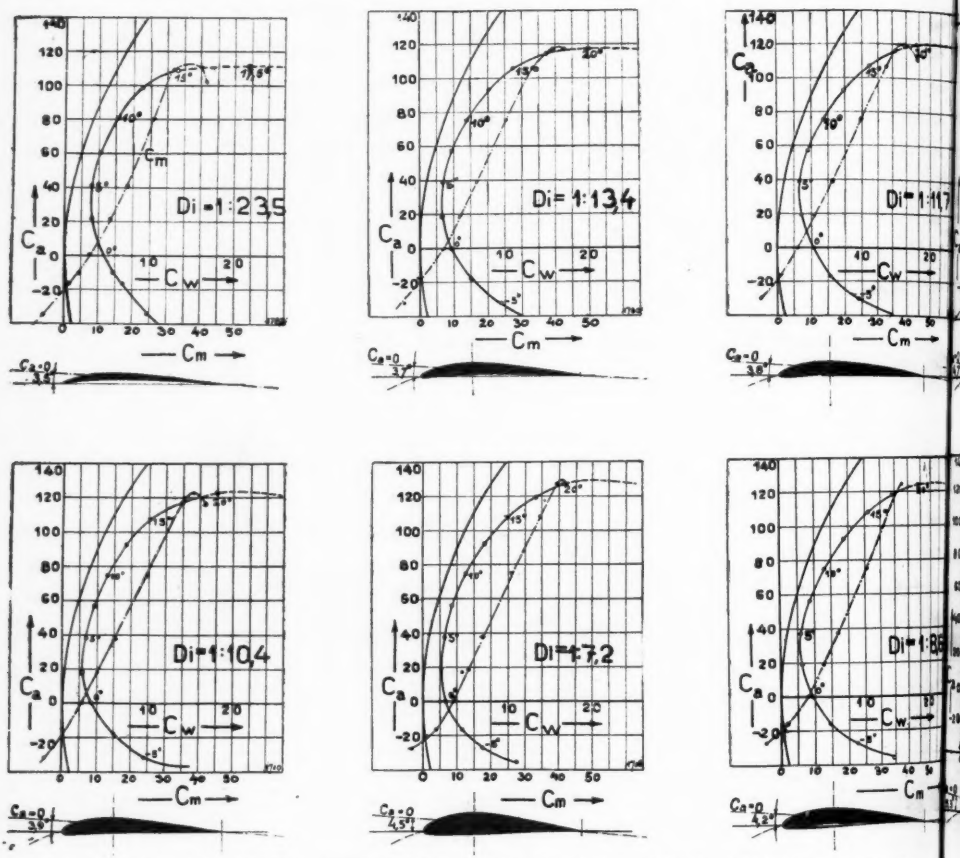

FIG. 7a.—*Systematic investigation of wing sections. Effect of thickness ratio Di (chord height/chord length); polar curves.*

workshops, and even the requirements of the market to a systematic examination before the original idea may be pronounced a success. It is necessary to see how far such considerations can be made serviceable to the ideal end, or if the idea must be modified in order to become feasible. Such an examination must be a necessary point of departure if it is to respect the confines of economy, the approved results of science and to apply her methods. But the work must remain subordinate to the uniform technical aim and therefore be under one control to allow for continuous adaptation, limitation and mutual influencing of

the individual departments busy with it. To repeat briefly, the realisation of technical ideas must be the fruit of an *institute of research* (Forschungsanstalt) uniformly conducted, but covering many branches. Such an institute I was able to create as a result of many years' hard work, aided by eminent collaborators, and I am indebted to this institute for my success in carrying out a technical innovation like the metal aeroplane from the first conception to the practical execution in a surprisingly short space of time and with a comparatively small expenditure.

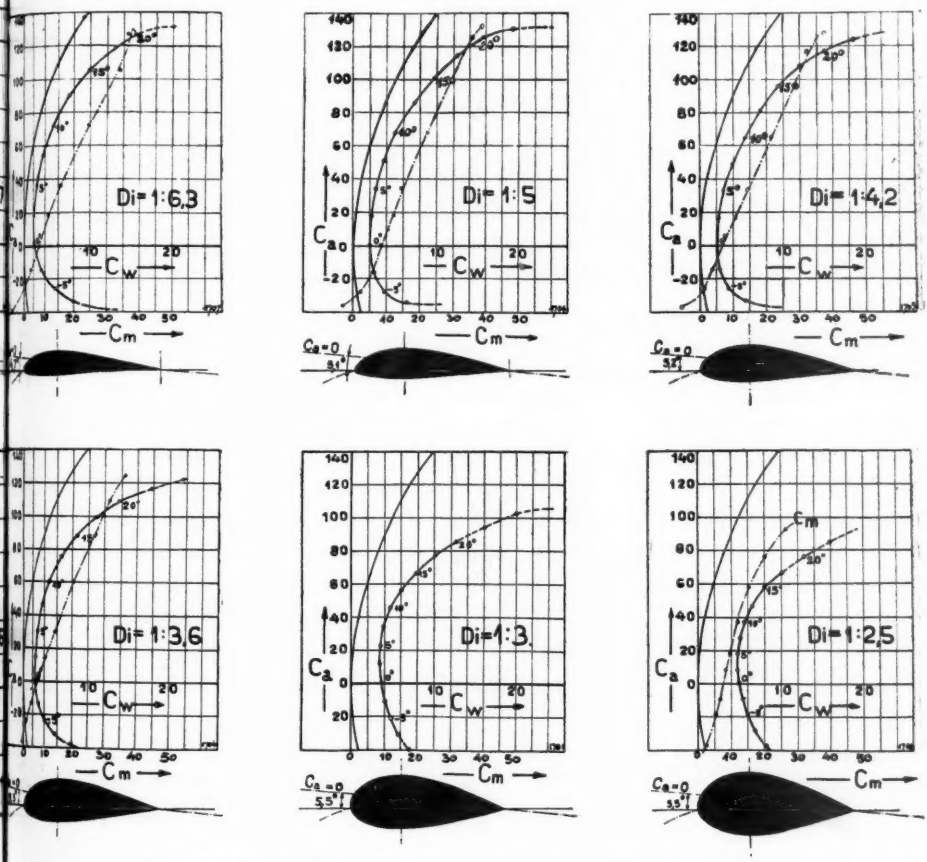

FIG. 7b.—*Systematic investigations of wing sections. Effect of thickness ratio Di (chord height/chord length); polar curves.*

I see the correctness of the method, founded on long preliminary studies, in the success of the very first metal aeroplane constructed by the Institute of Research (Forschungsanstalt), the steel aeroplane J1 (Fig. 1). It was finished within four months, and although diverging in every respect from the usual constructions and representing a complete innovation, had a remarkable performance for an experimental machine. It attained, according to an official report of the army authorities of 1916, an average speed on a return course of 170 km. per hour with an engine of 120 h.p. and a service weight of 1,010 kg., climbing

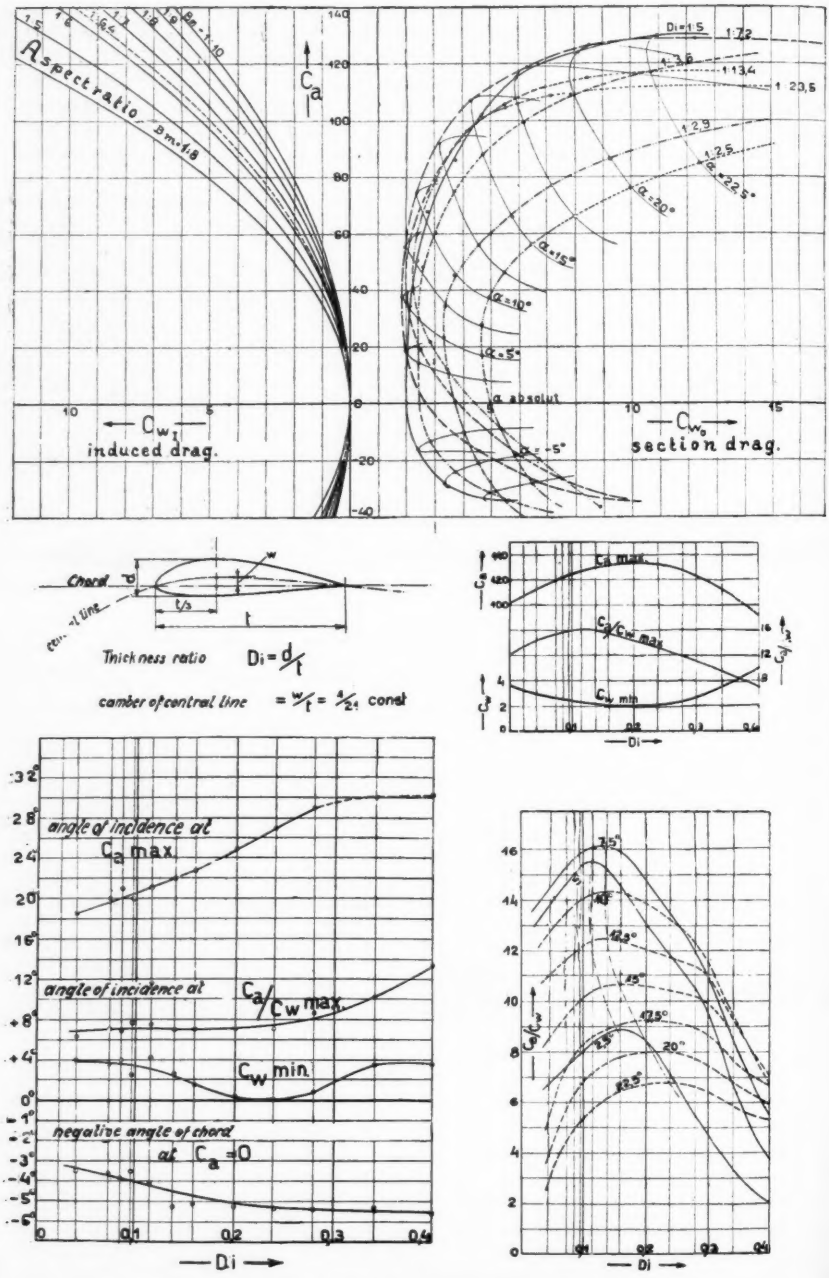

FIG. 8.—*Aspect of thickness ratio; assemblage.*

at the rate of 2-2.5 m. per sec. This corresponds to a ratio lift/drag of $>$ 10, or more accurately 10.7, assuming a propeller efficiency of 75 per cent., resulting from the formula $W/(75\eta P - V_h W v/3.6)$, where W = weight in kg., V = speed in kmm., η = propeller efficiency, V_h = velocity of climb.

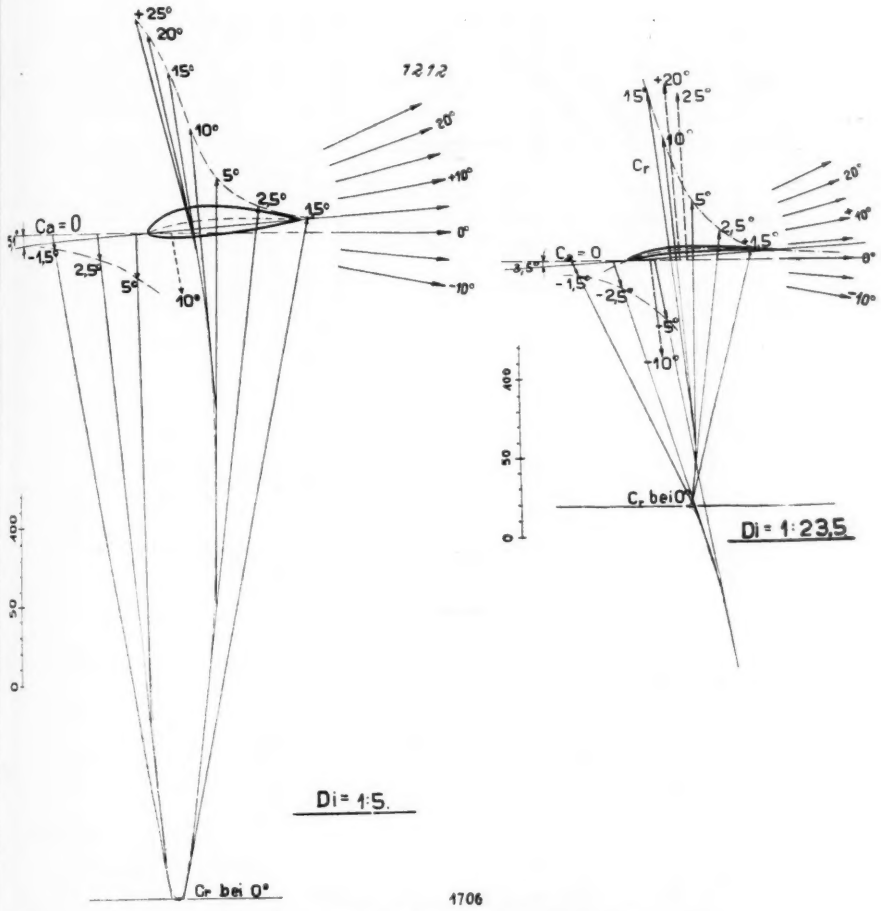

FIG. 9.—*Effect of thickness ratio (Di); diagram of forces.*

The construction of my metal aeroplanes is based on a patent, granted to me as far back as 1910 (Fig. 2).

I was then perfectly aware of the fact that the main end of aeroplane construction is to be found in a greatly diminished parasite resistance. Constructors had begun at the time to surround individual parts, exposed to the open current of air, with a flap or any sort of envelope in streamline form, with the object of decreasing the enormous loss of efficiency caused by such resistances. But this

was not sufficient. The streamlining, or fairing, or covering, must be shaped as a hollow space producing a minimum drag with a maximum lift. This idea is the nucleus of the patent. In other words, the structural parts of the aeroplane, as well as the power plant, crew and useful load, tanks and so on, must be located in the sustaining units, *i.e.*, the wings.

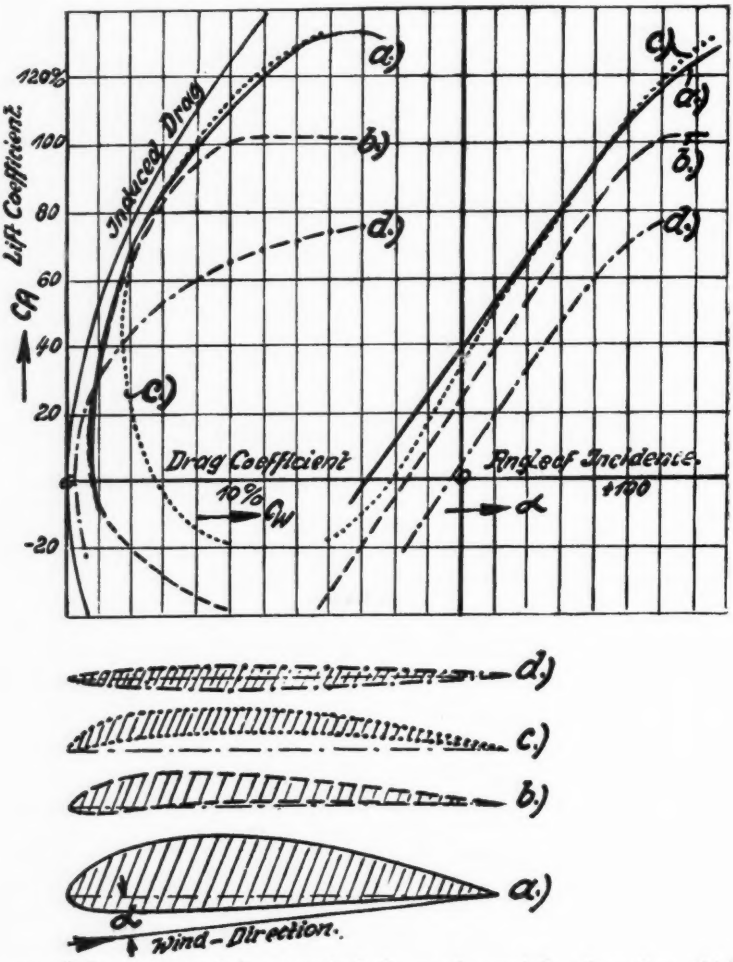

FIG. 10.—*Polar curves of four particularly good aerofoils of various thickness and camber.*

Aeroplanes of comparatively large dimensions afford in a particularly high degree the possibility of carrying out the conception upon which the patent is based.

It was in fact the creation of a swift and economical commercial giant aeroplane which I had in view as the ultimate object of the development. With such

craft the superior attributes of metal construction would become obvious in a most noteworthy degree.

Among the advantages the first is the greater durability. Wood is subject to the dangers of fire and decay, and splinters when breaking; it bursts and warps from the effect of humidity and change of temperature and the glued joints split; finally it is attacked by insects. No wooden aeroplane, serviceable for any length of time in the Tropics, has been produced as yet. Metal is free from all such drawbacks.

Structural parts made in wood also change shape and size; they swell or warp under the influence of heat and humidity, making necessary a continuous re-setting and trueing-up of the aeroplane. All this does not apply to metal, and a constancy of form is necessarily important in aeroplane wings, slight changes frequently producing a distinct deterioration of the aerodynamic qualities.

Thus metal aeroplanes have the advantage of greater durability, smaller expenditure for repairs and maintainance and of preservation of form.

Besides these we have the superiority of metal from the standpoint of the designer and constructor. The designer is less handicapped in the choice of dimensions and structural contours. Wood is obtainable only in fixed sizes and shapes of trunk and branch, furnished by nature, whereas metal may be obtained in a nearly unlimited variety of qualities and dimensions. We have sheet metal

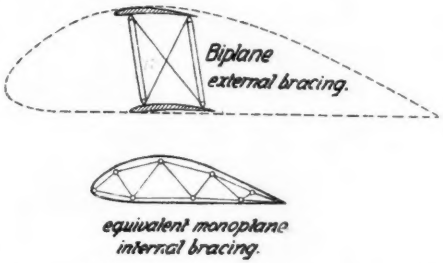

FIG. 11.—*Biplane cell and cantilever monoplane wing.*

down to a thickness of 0.004 inch, plates of more than 100 yards length, tubes, rolled section girders, etc.

Shaping of wood is limited, while metal might be given nearly any form by pressing, forging, casting, rolling, drawing, overlapping, etc.

And it is just as workable as wood for turning, planing, milling, boring, filing and punching.

Connections and joints, confined in the case of wood to glueing, bolting, mortising and wrapping with fabric, all of limited reliability, are much more varied and dependable with metal; as, for example, welding—autogenous or electric—riveting, screwing, folding and soldering.

Furthermore, the strength of metal is constant and can be stated any time in a reliable manner by tests, whereas the properties of wood are liable to change, wood being altogether highly unhomogeneous. Thus, the safety margin to be kept with wooden constructions must be much higher without giving a sufficient guarantee against undesirable surprises.

The result is that the application of modern methods of manufacture, such as mass production, interchangeability, standardisation, wide application of machine work, according to my opinion, can only be fully made use of in metal construction, and that the unreliable wood must be avoided even in the

building of single large aeroplanes, where the consequence of a crash can be disastrous both from the point of view of human lives and cost.

All these advantages are confronted by two drawbacks.

Constructions in wood require less expensive tools. This, however, only applies when the construction is on a small scale and disappears in mass production.

Again, wood is of smaller density. This argument is the one most generally advanced against metal, and with good reason, because this circumstance highly facilitates the attainment of great resistance to axial compression. But we have

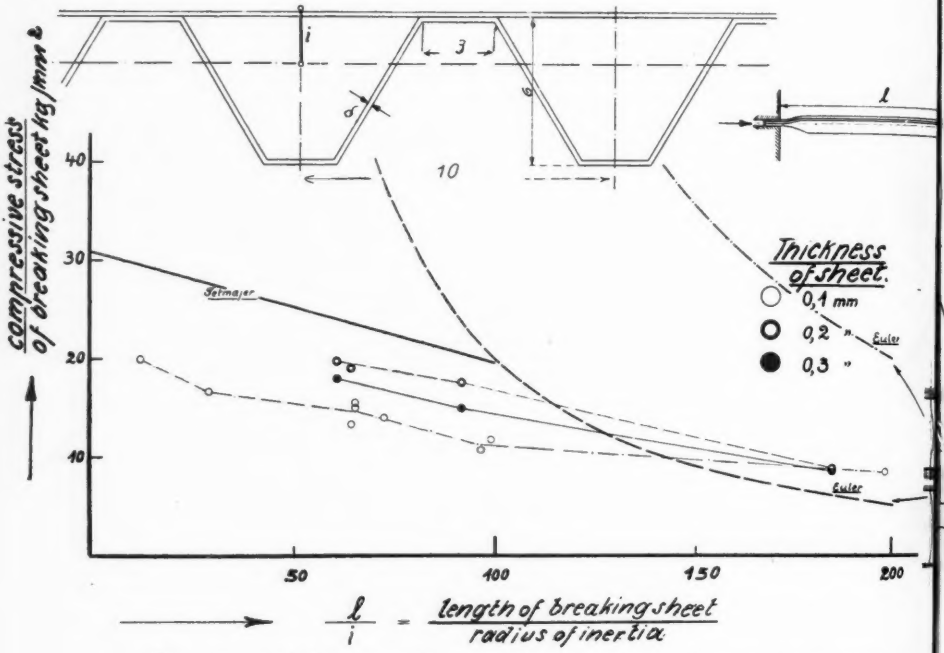

FIG. 13.—*Axial compression experiments with reinforced iron sheet.*

succeeded by means of extensive investigations in overcoming this advantage of wood by appropriate construction and the use of suitable material.

We have to view at present the question of the practical realisation of the thick cantilever metal wing. We had to investigate whether it was feasible to produce a wing which would combine with a thick section a low drag and a sufficient lift, and whether such wings could be constructed in metal in such a way that the aerodynamical attributes would not be suppressed by the drawback of too high a weight.

Up to this time only aeroplanes with the very thinnest wing sections had been constructed and the aerodynamical investigations in this province of science—as, for example, those of Eiffel or of the "Göttingen Aerodynamics Institute"—had likewise been conducted exclusively in this direction. There prevailed the general opinion that good results, both in lift and drag, could only be obtained with a thin wing.

I should hardly have mustered up the courage of starting the construction of thick wings, but for the fact that there existed already at that time highly interesting experimental researches, proving that in the case of rotary bodies, at any rate, the air resistance does not by any means depend on the section at right angles to the flow.

Still, as already mentioned, there did not exist any available aerodynamical investigations concerning thick wing forms; they had to be freshly created.

To this end I built first at Aachen and later on in Dessau a wind channel for the study of lift, drag, displacement of centre of pressure, etc.

My researches were not based on the usual aerofoil sections, but were started with bodies of elementary shape, such as ellipsoids, etc., and it soon appeared, when we passed to ellipsoids growing flatter and flatter, but of a constant perpendicular section relatively to the air flow, that the size of the section was not in fact of any deciding consequence and thick forms were not only admissible, but even—within certain limits—superior to thin ones.

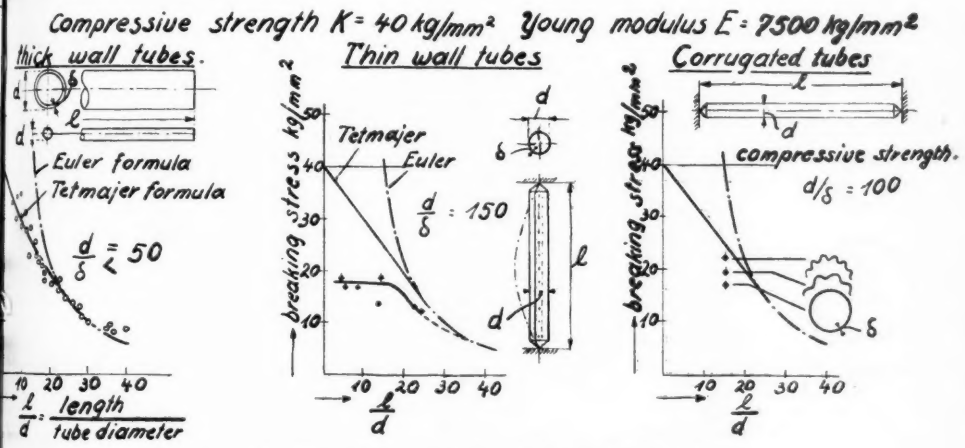

FIG. 14.—*Axial compression tests with duralumin tubes.*

The ensuing systematic investigations of aerofoil sections furnished quite a number of new results of great interest and importance.

Thus it became manifest that it is not so much the shape of the suction side and compression side of the wing profile in itself which has to be considered, but rather that of the central line, by which I understand a line equally distant from the upper and lower surface of the wing profile. The camber of this central line, more especially the magnitude of its leading angle at the head and the rear angle at the tail, are of extraordinary significance for the trend of the curve of lift and drag.

Fig. 3 presents a series of tests executed on models of the constant thickness ratio (chord-height/chord length) = 1 : 15.6 under a varying camber of the central line. (The thin aerofoil had been selected owing to such a model being on hand.) With increasing camber the maximum lift increases, while in the lower portion of the curve there takes place a marked augmentation of drag. The curves are shifted in a sort of parallel motion to the induced drag.

The results of tests on the variation of the trailing angle of the central line are shown in the following Figs. 4-6, representing besides values of c_a and c_w

the maximum lifts, zero angle lifts, minimum drag and the range of lift for values of $c_w < 0.03$, corresponding to the various aerofoil sections.

But the most important and surprising data were furnished by the experiments as to the effect of the ratio of thickness.

In Figs. 7a and 7b are shown c_a and c_w curves of a series of wing forms with thickness ratios varying from 1 : 23.5 down to 1 : 2.5, with an unvarying central line. My most extravagant expectations were surpassed: the thick aerofoils proved not only equivalent to the thin ones of some series, but even superior, within certain limits.

The following resumé of this series of tests shows (Fig. 8) that the most favourable conditions both of lift and drag are found for a thickness ratio of about 1 : 7 to 1 : 5. It will be noticed that even wing forms with a convex lower surface, so strictly shunned up to the present, are quite admissible.

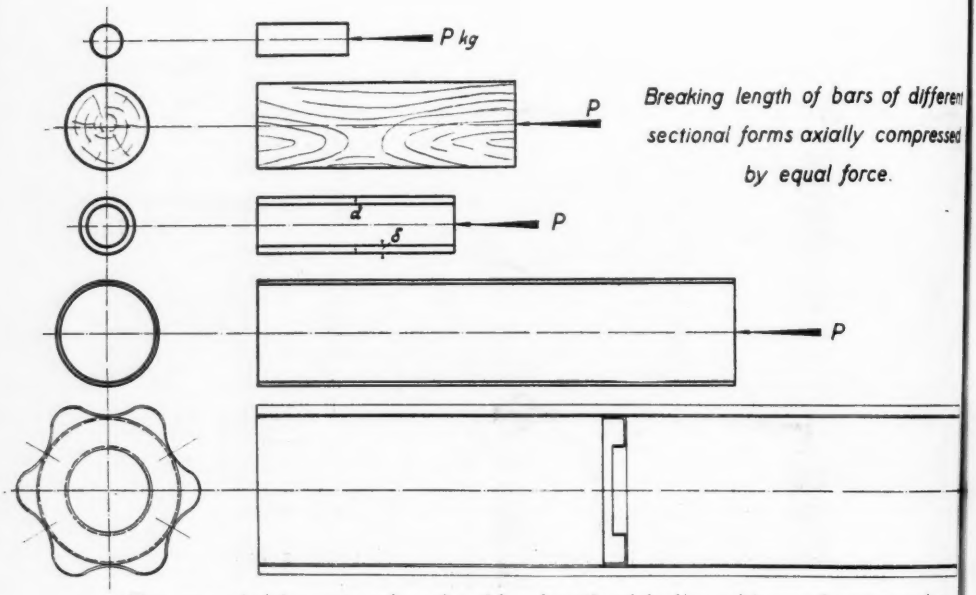

FIG. 15.—*Axial compression; breaking length of bodies with equal compressive stress.*

Even in regard to the displacement of the centre of pressure (longitudinal stability) the thick wing at least not inferior to the thin one. You will observe in Fig. 9 that this displacement is nearly equal for both sorts of sections, a closer investigation having even been somewhat in favour of the thick aerofoil. aerofoil.

It is a consequence of the long lever arm at which the drag component at zero-lift operates, that a high torsional stress upon the wing is exerted in a dive. I shall return to this point later on.

The subsequent diagram (Fig. 10) is particularly illustrative of the superior merit of the thick wing form; it gives the typical polar curves of a thick section besides those of a highly and a slightly cambered as well as a symmetrical thin wing section. The tests were selected from those published in the latest report

of the Götingen Aerodynamics Institute, taking in every case *the* aerofoil, which gave the best result in its group.

If the object be to attain a maximum of horizontal speed with a thin wing form, only a form with a slight camber (*b*) with a minimum drag comes into account, whilst for a satisfactory performance in climbing, starting, alighting, etc., a strongly cambered section (like *c*) with high maximum drag is required. Curve *a* of the thick form envelops curves *b* and *c*; hence the thick section combines the advantages of both the strongly and the slightly cambered thin one—even leaving out of consideration eventual resistance of bracings to be added for the thin section.

Resuming, we see that the need of housing the parts producing drag within the wing coincides in a surprisingly happy manner with the requirement of an aerodynamically good aerofoil.

At the same time the realisation of another demand on the wing is facilitated by the thick aerofoil: that of sufficient strength with smallest weight. This results from a consideration of the forces acting on the wing.

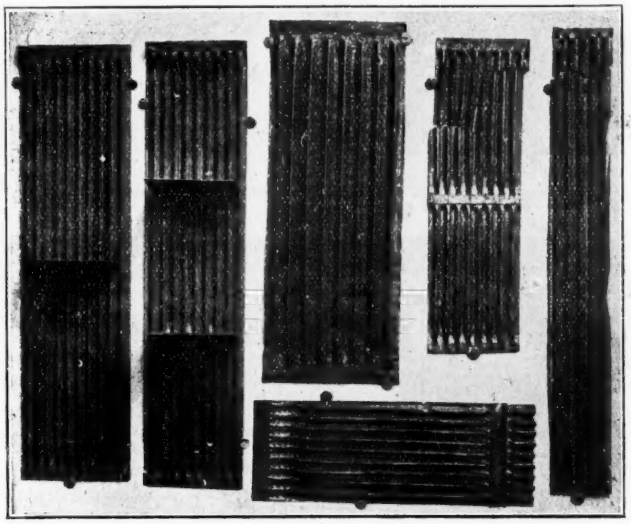

FIG. 16.—*Examples of sustaining iron cover of J.1.*

The characteristic stress upon the aeroplane wing consists in the high bending moments, arising from the concentration of the greatest part of the aeroplane's weight and the total useful load in the middle of the aeroplane; while the counter-pressure of the air is about evenly distributed over the wing; the bending moment increases the larger—in consideration of a favourable aspect ratio—the span is chosen. Also there is always produced in cambered wings a torsional moment, an attempt to twist the wing in relation to the body, which eventually attains very high values in a dive.

The bending moment must be absorbed by tensile and pressure forces. If we consider the wing as a framework, the tensile and compressive stresses increase, the lower the constructional height, *i.e.*, the distance between the extended and the compressed parts.

The problem of great structural height has so far been solved very cleverly in aeroplane construction by the biplane cell. An upper and a lower wing are employed which are joined together by means of struts and wires and so produce a framework. The air resistance of those connecting pieces is, however, very considerable, this circumstance forming the great drawback of the biplane cell.

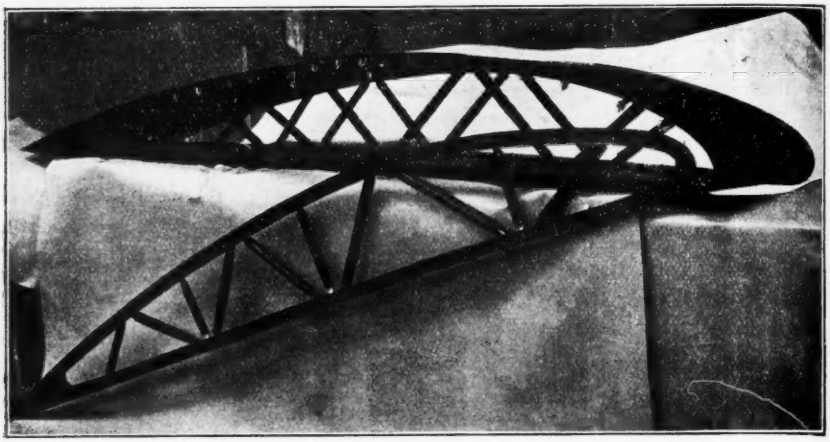

FIG. 17.—*Wing portion and rib of the iron wing.*

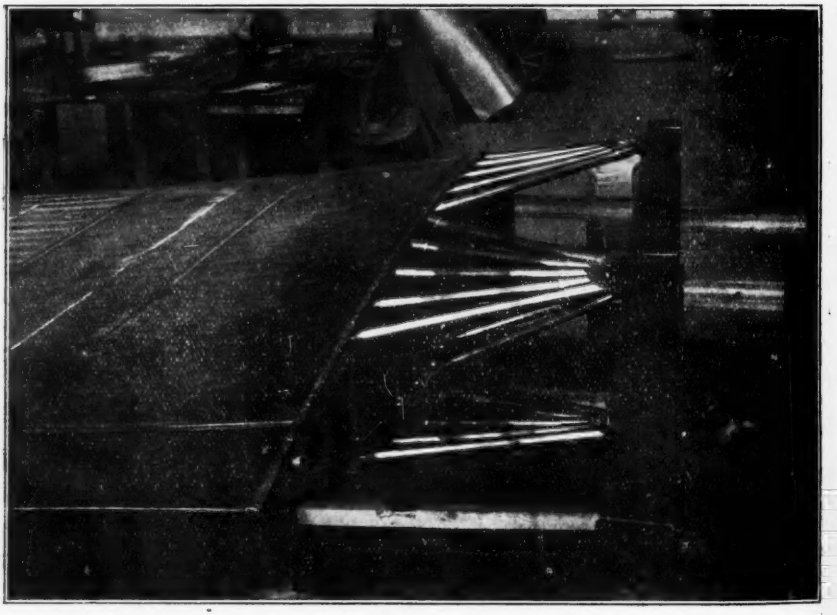

FIG. 18.—*Connection of iron wing and fuselage by claws.*

Now the method of avoiding this shortcoming is indicated in Fig. 11. It consists in enveloping the cell in a suitable thick wing section. In this way the biplane cell is transformed into the thick cantilever wing, the drag of which is distinctly less than that of the biplane cell under an equal lift, and which in addition forms a large hollow space for the location of bodies which would produce drag if exposed. These were the reflections which served as a basis for the patent.

It will now be interesting to examine the biplane question, setting aside the usual standpoint of the braced biplane cell and imagining it to be a combination of two cantilever monoplanes. How will such a cantilever biplane compare with an aerodynamically equivalent monoplane?

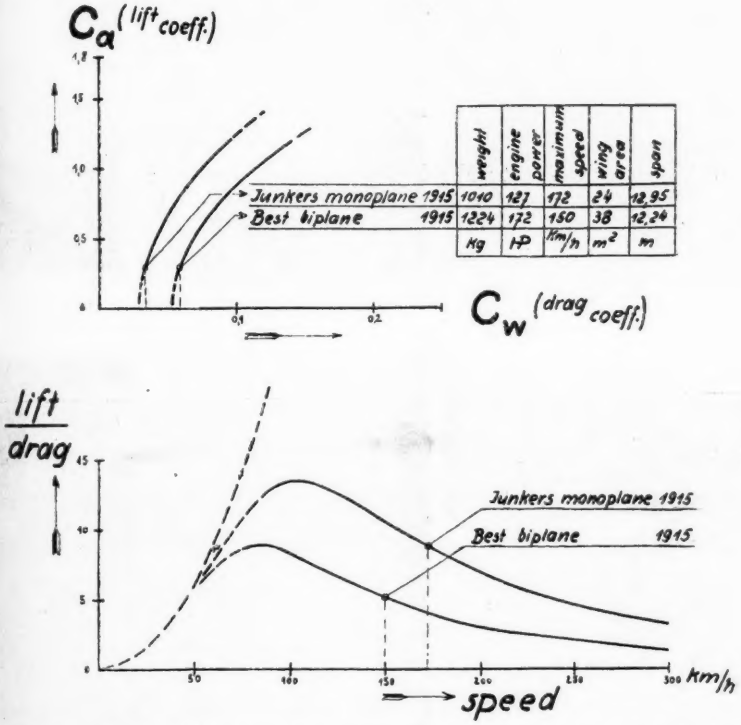

FIG. 19.—*Polars of the first iron plane, J.1, compared with the Rumpler biplane R.C.I.*

Now such mono- or biplane types must be considered as of equal aerodynamical efficiency, which exhibit the same drag for the same aerofoil section, total supporting area and lift. According to Prandtl's multiple plane theory, which agrees very well with experience, the span of the monoplane is certainly greater than that of a biplane of "equal value," the differences not being, however, very considerable (20 per cent. or less), whilst the length of the chord and consequently also its height is in the monoplane nearly double that of the biplane.

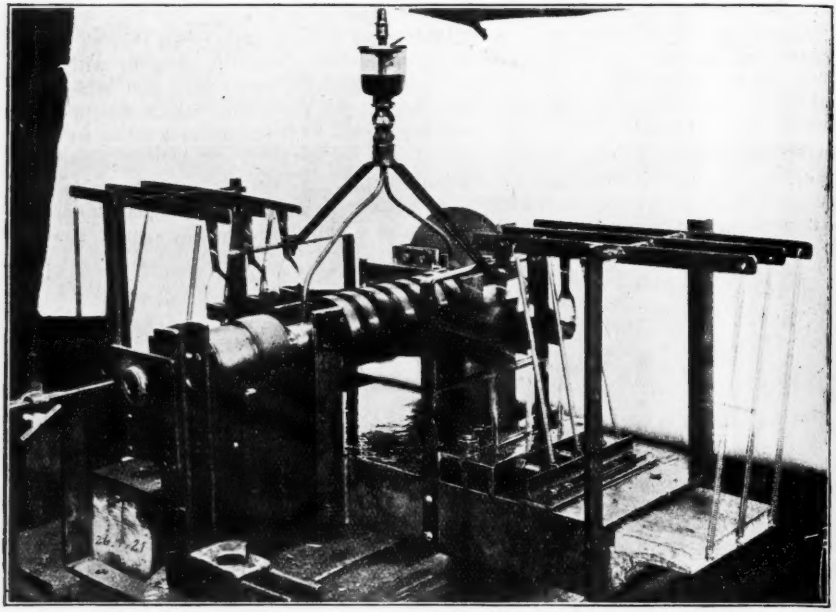

FIG. 20.—*Device for fatigue tests of sheet metal bands.*

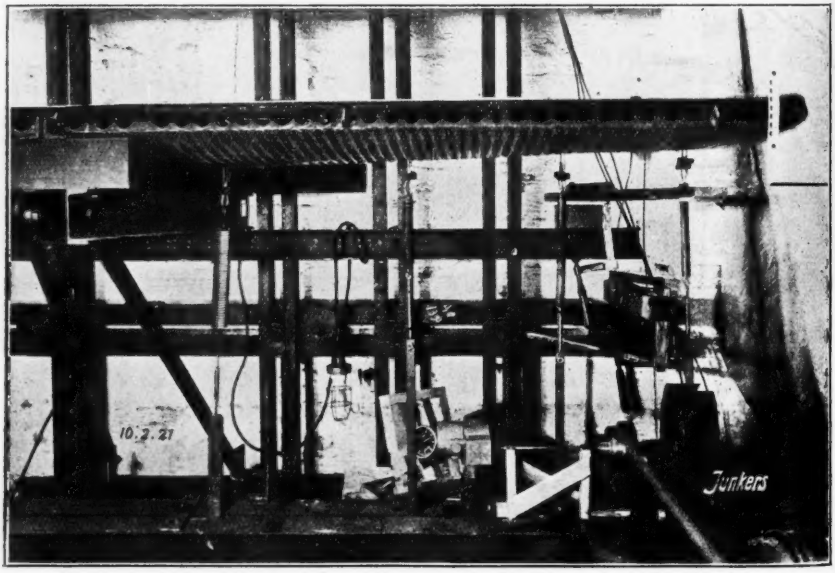

FIG. 21.—*Arrangement of vibration tests on tail plane.*

Thus the ratio of height to span is undoubtedly best with the monoplane; the strength being equal, the latter is the lighter, and in addition has the advantage of having a larger hollow space. Consequently I came to the conclusion that the cantilever monoplane is to be preferred to the normal multiple plane type in every respect.

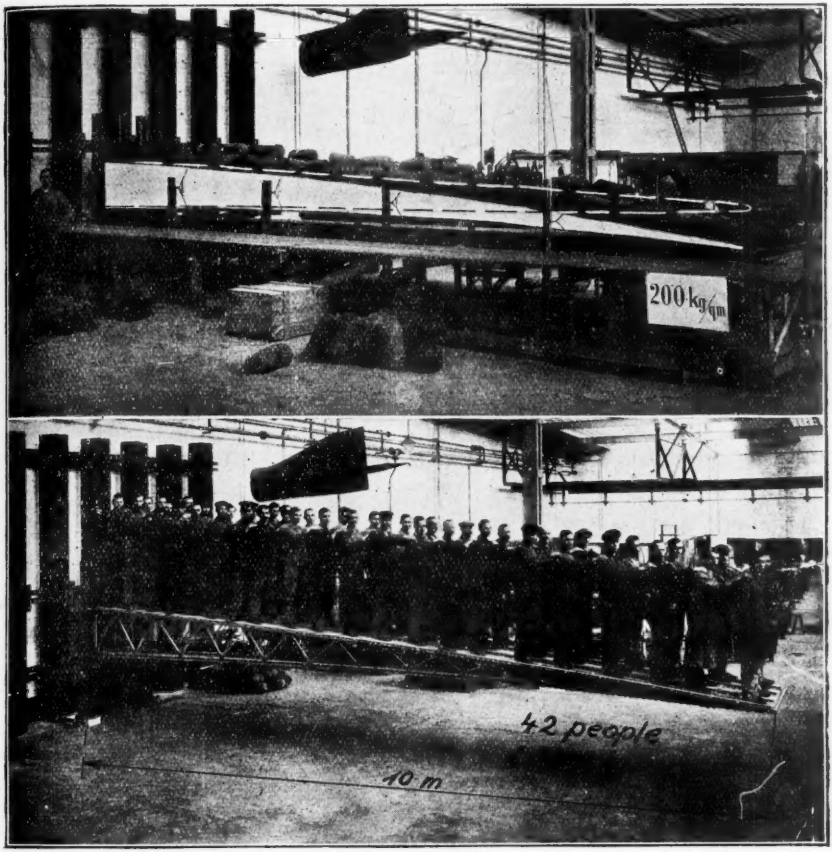

FIG. 22.—*Experimental framework wing; area* = 15 m^2; *weight* = 110 *kg.* (7·4 *kg./*m^2); *loading capacity* = 4,500 *kg.* (300 *kg./*m^2).

If the permissible tensile and compressive stress be given, the weights of the wing parts conveying the air forces upon the fuselage may be readily computed from the structural height and the span. In Fig. 12* is seen the result of such a calculation for a surface loading of 50 kg./m^2, the assumption being made that the outer cover of the wing can fully stand the indicated theoretical tensile and compressive strains.

Such a wing—we shall call it the ideal wing—would have the weight indicated by the lines of the diagram per unit of surface. Thus, the weight per square metre would be in direct ratio to the span of the wing.

* Not printed.

We see that the "ideal wing" is of extraordinarily light weight, lighter by far than the usual wings of wood and fabric. How far we are as yet from this ideal is demonstrated by the dots in the diagram, representing metal wings which have actually been built.

Now the reason for this great divergence between the effective and the ideal weight is to a great extent to be found in the fact that the theoretical compressive strength of the wing parts exposed to the pressure forces cannot be utilised on

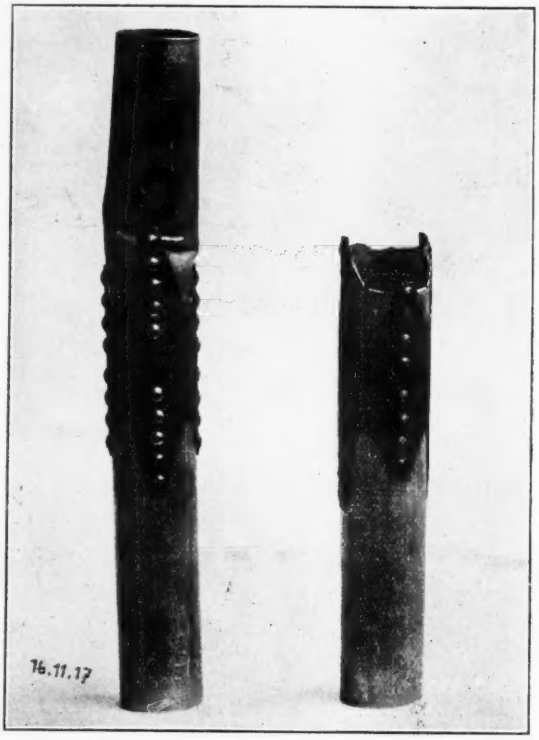

FIG. 23.—*Telescope joints for tubes.*

account of axial compression buckling; or to state it differently, the stress on the members subject to pressure forces may but attain a fraction of the theoretical resistance to compression. Therefore axial compression is the most material question for the construction of metal wings.

I have carried out a series of very exhaustive researches concerning the process of axial compression or lateral flexure.

I tried to apply the well-known fundamental formula of Euler and the results of the experimental researches of Tetmajer with reference to the relation between compresive stress on the one side and breaking length under lateral flexure and radius of inertia on the other side. Our relative tests proved, however, that the range of validity of those formulas did not extend to the thin-walled bodies concerned. If the thickness remains beneath a certain minimum there is produced a

local bulging out which can to a certain extent be remedied by means of special devices (*e.g.*, the application of an undulated stiffening cover).

In Fig. 13 are produced some results from tests of axial compression of sheet iron of various thickness, stiffened by a second layer of corrugated sheet metal. It will be noticed that the actual stress due to axial compression lies, for such thin walls, appreciably below the stress theoretically admissible according to Euler-Tetmajer.

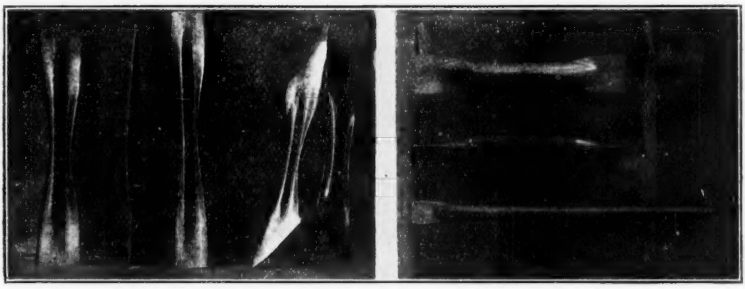

FIG. 24.—*Frame struts.*

A similar behaviour is shown by tubes. Whilst, according to my tests, tubes easily reach the Euler-Tetmajer resistances to axial compression down to a certain thickness of wall (Fig. 13a, $d/\delta \leqq 50$), this does not hold any more for $d/\delta = 150$. Here we perceive already at a slight compressive stress a local bulging out, causing the tube to give way.

In Fig. 14 is plotted the axial compression breaking length of a number of tubular bars, metal and wooden, exposed to the same compression strength.

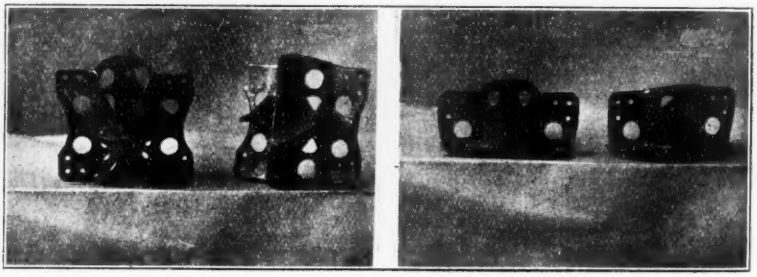

FIG. 25.—*Joints.*

This length can be increased, but only to a certain limit, by a simple enlargement of the diameter (radius of inertia), the thickness of the wall then being diminished in agreement with the constant section of the material. Beyond that limit provision must be made against local deformations. As my experiments have shown, this can be done by the superposition of corrugations on the tube wall, which render the radius of curvature in every part of the tube wall smaller than would correspond to the increased diameter of the tube. In this way a method was found by means of which very light structural parts may be obtained in metal even if they are subject to stress from axial compression (buckling). We have, for example, succeeded in reducing the weight of tubes with a buckling length

= 1 m. under a load of 1 ton to 0.12 kg. by the use of duralumin, whilst a solid wooden bar of the same load and length weighs more than five times this, viz., 0.63 kg.

In the same manner were obtained relations between limiting breaking length under axial compression, radius of inertia and thickness of wall for a variety of shapes and materials.

This preparatory work finished, the construction of a thick metal wing could be started.

In order to absorb, with the use of a minimum weight, the high bending and torsional moments conveying the air forces upon the hull, two principles were applied for the design of the wings, viz. :—

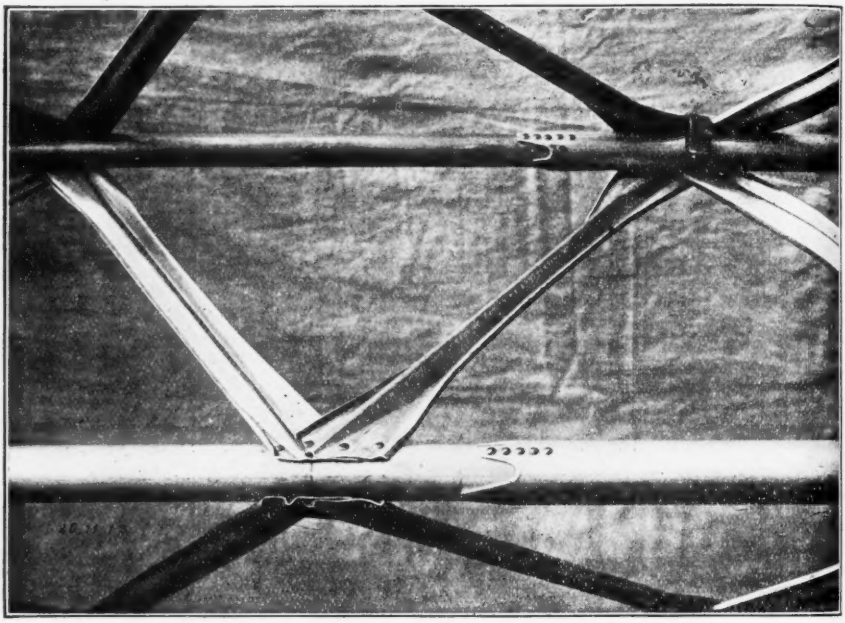

FIG. 26.—*Connection of tubes with each other (telescope joints) and with struts (riveting).*

1. The parts ultimately exposed to the moments were placed as far as possible from the neutral axis so as to give the lever arms of the moments a maximum length and consequently render the corresponding compressive tensile and shearing forces as small as possible.

2. All parts of the material wing cover included must share in the absorption of the moments.

The last named requirement was especially important in the case of iron construction, since the supporting surface had to possess sufficient resistance to local strains, *i.e.*, a certain amount of firmness; but in consequence accounted for a great part of the admissible total weight of the wing.

Thus, the theoretically best design appeared to be the system of the so-called "supporting cover," that is, all tensile, compressive and shearing forces are taken up by the wing cover.

We had at disposal as material of construction sheet iron 0.1 mm. thick used for magnetic purposes, in plates of a very disadvantageous small size and of quite unsatisfactory properties of resistance and elasticity.

To make the surface built of this iron plate resistant and rigid, a second layer of corrugated sheet metal was welded to its inner side (Fig. 16). On the

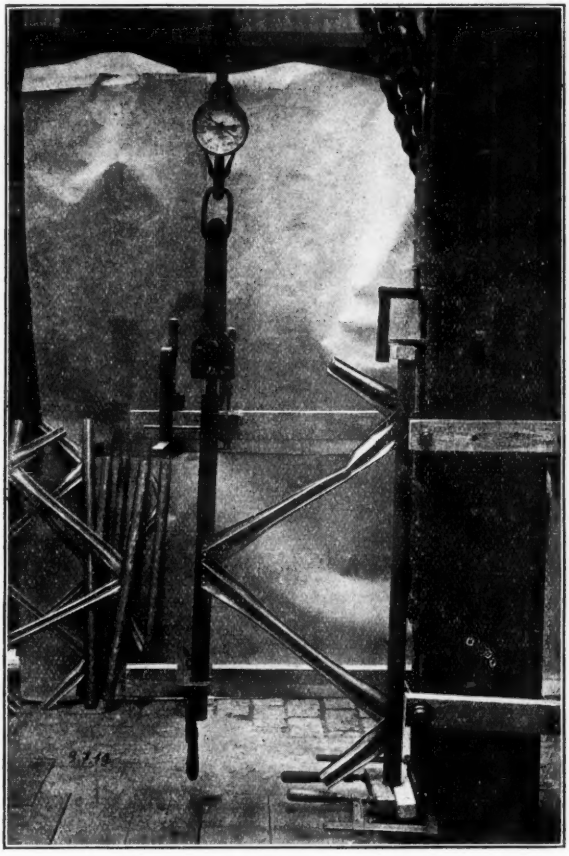

FIG. 27.—*Test of connection between struts and spars.*

basis of the above experiments on axial compression the admissible undulations (radius of inertia) corresponding to the thickness of 0.1 mm. were determined whilst the intervals (viz., the breaking lengths under axial compression) in which the surface had be propped up by bulkheads or ribs (Fig. 17) were given by the dimension of the iron plates.

The short portions or wing sections thus formed were subsequently joined by welding to produce the whole wing. These joints were very difficult. The place of welding had to be reinforced correspondingly to the resistance of the individual wing portions by the insertion of a sort of small iron plate shoe pro-

truding into the undulations; in this way the entire surface was utilised for elastic deformation.

Without due consideration of this requirement, which gives rise to many a difficulty in design and construction, the surprisingly good behaviour of the metal wing would not have been achieved; on the contrary, a splitting up of the surface and the disastrous breaking of the wings due to unsymmetrical loading of the material would have unavoidably ensued.

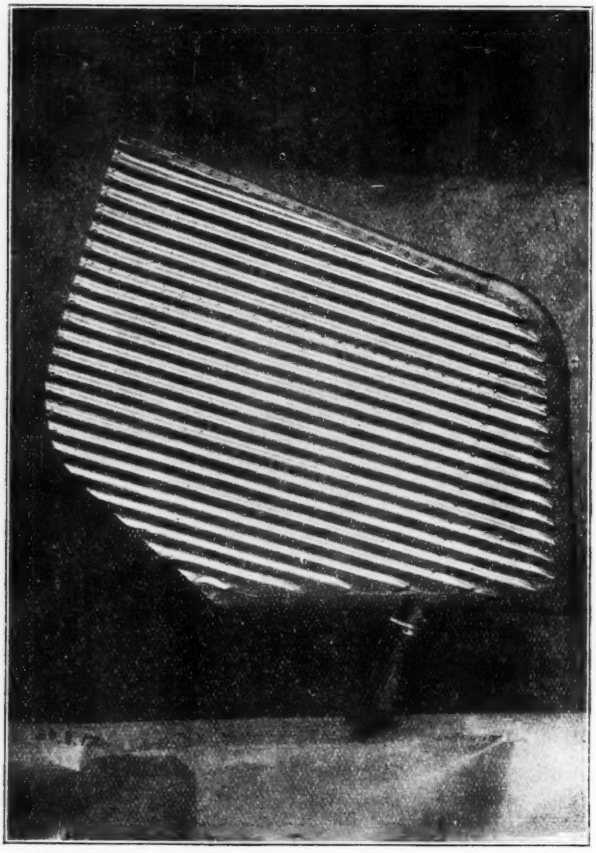

FIG. 28.—*Rudder; illustration of connection of corrugated plate surface to leading and trailing edge of wing.*

After test wings of increasing length had been constructed and tested in the usual manner by sand loading until failure, the building of a whole aeroplane was started, the single-seater monoplane, J1.

Further difficulties had to be overcome in joining the wing to the body of the machine.

Since the space necessary for the location of engine and pilot had to be placed approximately at the point of intersection of body and wing, it could not be

interfered with, and the supporting cover could not be conducted without interruption across the fuselage. Hence the forces of tension and compression distributed over the surface had to be concentrated at special points and be transferred from them in roundabout ways from one side of the body to the other—a task which, on account of the low elasticity of the disposable material, alone proved to be about the most difficult I ever had to encounter in my engineering experience.

Fig. 8 shows one of the many experimental contrivances designed to this end, all of them however yielding no satisfactory solution.

After the lapse of four months (all preparatory work, testing wings, etc., included) the aeroplane was finished, the achievement being so much the greater

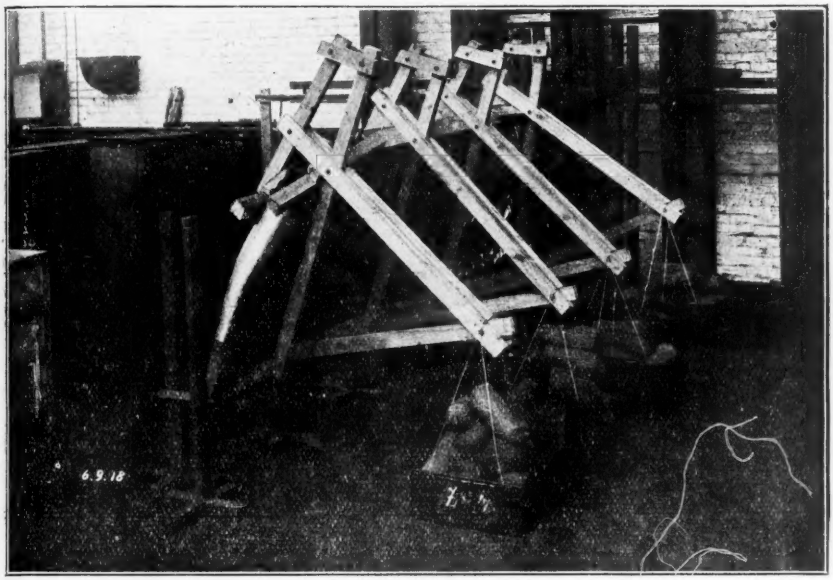

FIG. 29.—*Breaking test of wing for torsion.*

considering the perfect novelty and extraordinary difficulty of the task to be accomplished, much harder in fact than the subsequent duralumin constructions (Fig. 1).

The span of the aeroplane was 12.95 m., the length overall 8.62, the supporting area 24 square metres, the total weight about 1,010 kg. The engine was a Daimler Mercedes of 120 h.p.

The first trial flights were made at Döberitz in December, 1915, and the above mentioned speed test was made in January, 1916, when a speed of ca. 165 km. or 102 miles per hour was attained.

In Fig 19 is plotted an approximate polar curve of the aeroplane based on the above tests together with a few wind tunnel experiments, which do not, however, aspire to great accuracy. This is compared with the polar of the best German plane at that time, the Rumpler biplane R.C.I.

This iron plane has been flown by many excellent aviators, among others by the well-known aeroplane constructor Fokker, who stated in a test flight that its

speed exceeded by 20 km. per hour the fastest machine of that period which had started simultaneously.

Although the welded iron wings fully responded to the requirements of resistance, I abandoned the system of " supporting cover " and altered the construction of the wings entirely. This change had become necessary on account of the great weight of the iron wings, amounting to some 12kg. per m^2 with a length of (one) wing of 6m., and was the cause of a very bad climb of the aeroplane.

This heavy weight was not only the consequence of the metal selected (iron), but also of the particular design which allowed only to a small degree the utilisation of the compressive strength of the material.

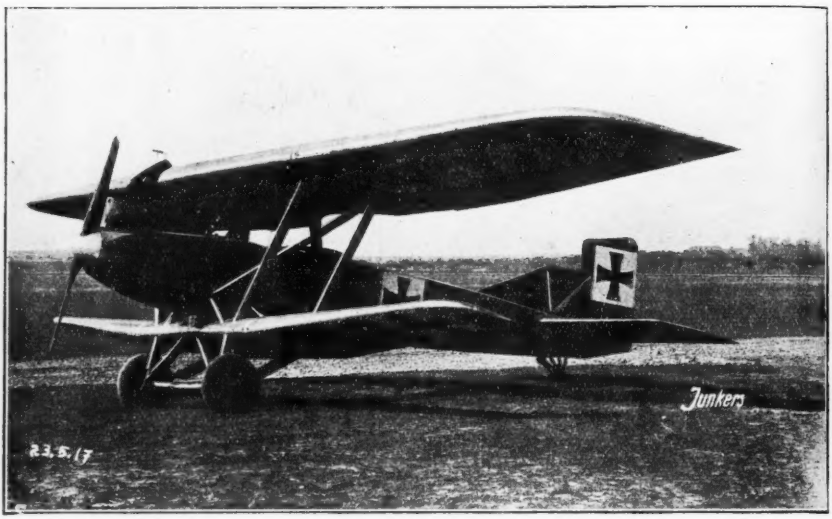

FIG. 30.—*Infantry armoured aeroplane J.4 (Junkers J.1): 200 h.p. Benz: service weight 2,176 kg.: speed 155 km. (97 E.M.)/hour: climb 2 km. in 32 min.: supporting area 50 m^2.*

I have already mentioned that the necessity of using the " supporting cover " (*i.e.*, no internal spars) system resulted from the fact that with the use of iron the weight of the cover capable of fully absorbing the local stress made up nearly the whole of the disposable wing weight.

With regard to the unit of weight, duralumin has a smaller tensile and compression strength than a good steel. It is, however, of lower density, and thus for the same weight (*i.e.*, same tensile and compression load) it will be thicker. It will therefore be possible to make the wing cover lighter with regard to local loading, for the corrugated duralumin will have deeper corrugations than the thinner iron covering of equal weight, and will then be capable of transmitting greater bending moments.

This circumstance made it feasible to work with a simple corrugated plate cover of small weight. Thus we were freed from the otherwise imperative necessity of letting the cover itself partake of the absorption of the high moments, and were enabled to use for the absorption of these moments special structural parts, which on account of their appropriate shape allowed a much

higher stressing of the material in regard to axial compression. Exhaustive tests in this respect proved that as concerns buckling drawn tubes stand best among all section-forms of equal wall thickness.

It was, therefore, soon decided to let the covering surface partake only of the local stress and part of the torsional stress, and to meet the high bending moments by a frame or trestle of tubes in the interior of the wing.

It became necessary to make a close study of the new constructional material in order to accommodate and to adjust design and workshop treatment to its properties. The investigations included resistance of material after varying treatment by heat; so-called fatigue phenomena; corrosion and modes of connecting duralumin parts with each other, etc.

The final result of all this experimental research was that duralumin will meet, when correctly treated, all requirements coming into question. But it must

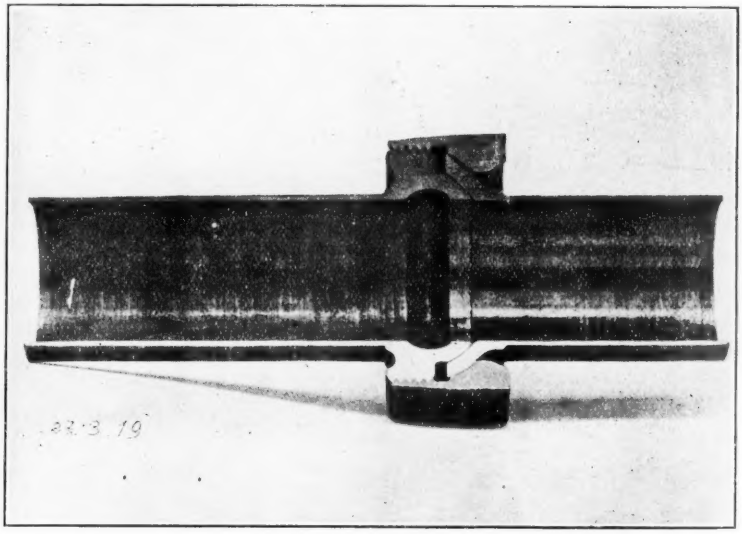

FIG. 31.—*Ball and socket joint between wing and fuselage.*

be said that a good deal of work was necessary to find a suitable treatment by which some of the rather troublesome properties of the material could be overcome, for example, its liability to corrosion. In regard to "fatigue" under varying load, it appeared that duralumin is in no way inferior to iron (Fig. 20 illustrates the arrangement of the fatigue tests). More important is the bad welding of duralumin. We have not yet succeeded in removing the very marked deterioration of the material produced by the welding process, which by itself is quite feasible. But we have found that welding can in all cases under consideration be readily replaced by riveting. The rivets are not loosened to any appreciable degree by the vibrations, to which the whole aeroplane is subject by the work of the engine. We tested this in the manner shown in Fig 21. It shows, for instance, a tailplane made to oscillate by an electromotor, the rotation of the motor corresponding to the impulse-number of the aeroplane engine. The result was that rivets showed no loosening, even after 1,000 hours, and under a stress exceeding the strain occurring in a running work.

But before we could attack the construction of framework wings, there had to be created appropriate designs for such, together with the most suitable forms of construction selected on the strength of systematical tests with respect to resistance, weight and care of manufacture. To such tests were exposed all the single parts, as spars, struts, joints, telescope or pipe clip connections, etc., as well as their assemblages to girders and complete wings.

The first wings tested were of a simplified shape (Fig. 22), the head and tail parts being omitted as immaterial for resistance, and the middle substituted

FIG. 32.—*Ball and socket joint between wing and fuselage.*

by a row of triangular girders connected in parallel. The tests of a series of such experimental wings of increasing dimensions proved that we were on the right track; the construction of regular wings could be attacked.

The basis of the construction is the spar. For these duralumin tubes of suitable diameter and thickness are taken, which thickness must not remain below a critical figure determined by buckling tests described above. If drawn tubes are not in the market in the required sizes, they may be substituted by plates round

and riveted. Experience, as a result of exhaustive tests, has proved, however, that they had to be carefully constructed under expert control.

For connecting two tubes lengthwise telescope joints are used (Fig. 23), after a patented procedure resulting from a long series of experiments.

After that the spars must be connected to the girders. The struts serve this purpose (Fig. 24), appearing either as tubes flattened at their ends, or as so-called Z-shaped struts. The fastening of the struts to the tubes is effected according to circumstances, either by means of special welded joints made of iron and tested for resistance (Fig. 25) or by riveting (Fig. 26).

The resistance of the struts and their connection to the spars is examined on special testing girders by the application of an axial force to one tube, while the other is held fast (Fig. 27).

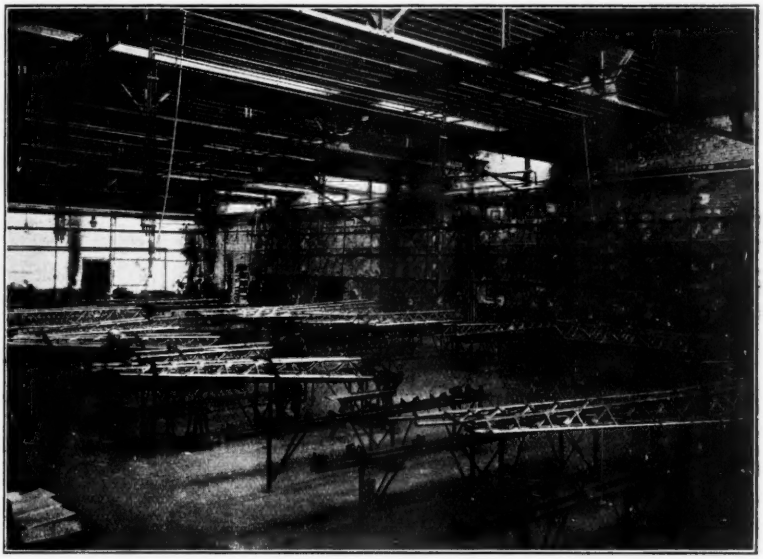

FIG. 33.—*Manufacturing the frame works for J.4.*

The cover of corrugated sheet metal must satisfy the high requirements exacted by aerodynamics and still be of light weight.

Wind channel tests have proved so far that the air resistance on the wings is but imperceptibly increased by the corrugations which augment the frictional surface of the wing by approximately 15 per cent.

From the standpoint of resistance the bending stress, due to accidental and local forces, such as shocks and jerks in transportation, treading upon by men, etc., is of importance. The problem was to find the most advantageous length and height of corrugation with which the wing surface will stand a given load and has a minimum weight; numerous tests were required for this.

The connection of corrugated plates with each other, and more particularly with smooth plates, is not always a convenient job, and often required much constructional acumen combined with great experience in the treatment of duralumin. You perceive a typical instance of such connections in Fig. 28, showing a rudder.

The transition from the smooth sheet metal covering of the leading edge to the corrugated plates upon the lateral areas is clearly discernible, and equally so the formation of the trailing edge.

Fig. 29 shows a loading test for torsion of the completed wing performed until failure.

The first entirely completed aeroplane type in durmin was the armoured machine J.4, constructed in 1917, the first aeroplane manufactured in larger series by the factory (Fig. 30).

The building of this aeroplane was the result of a request by the Army authorities for a heavy armoured aeroplane, which was to be of the biplane type, as was expressly stated.

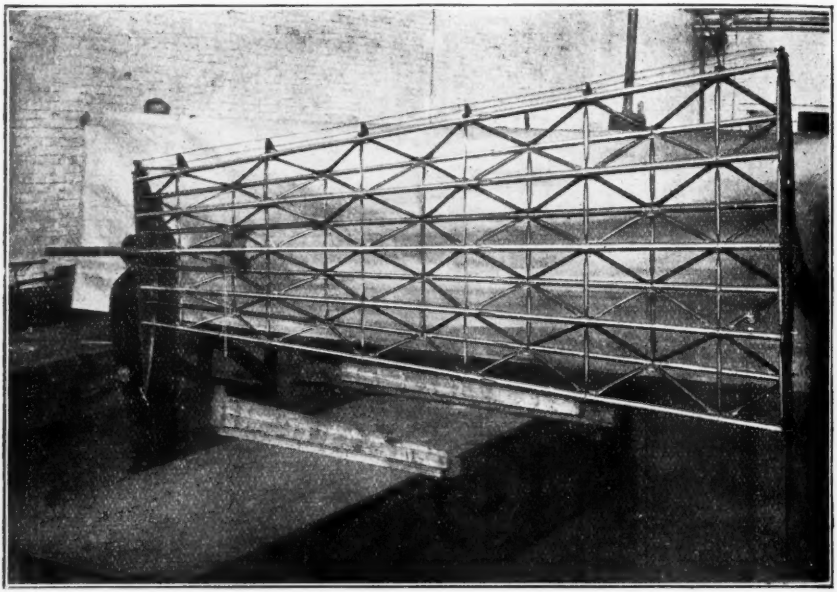

FIG. 34.—*Tube frame work.*

In this plane the fuselage is suspended on both sides to the middle parts of the wings by four struts, a canopy being thus formed. The wing is composed of three sections as a framework wing, the spars running from the wing's tip to the canopy portion, where they are screwed to the spars of the latter by special ball and socket joints (Fig. 31). Each one of those spars represents therefore a direct prolongation of the wing spars. The wing can be detached from or attached to the middle piece in a few minutes (Fig. 32). The screwing joint has shown up well, and has been preserved also in the subsequent aeroplane types.

Fig. 33 shows the method employed in the manufacture of the wings. The spars are put down in special gauges and connected to the girders. The latter are joined to the framework (Fig. 34), upon which is laid the covering surface, and conected to the spars by rivets (Fig. 32).

The riveting of the struts and of the corrugated plate-cover to the tubes is done by a special patented procedure, the rivet head being made in the interior of the tube by counterpressing an aurol pushed into the tube (Fig. 36).

A feature of the armoured machine is the peculiar armoured box (Fig. 37), which served as backbone of the fuselage structure and proved such a success that in many a nose dive and capsizing, both engine and crew remained untouched.

The apparatus is constructed for safety from distant firing. The construction was statically indeterminate (redundant parts), and the spars could be damaged repeatedly without impairing the flying capacity of the machine. Fig. 38 shows part of a wing of such an aeroplane which has stood more than 400 hits without failing.

The weight of the aeroplane was 2,176kg., with a supporting area of 50 sq. metres, the engine 200 h.p. (Benz) being, however, perceptibly overloaded.

In spite of widespread prejudice, I did not refrain from the further study of the monoplane. It was of the utmost importance, therefore, to revise the relative position of the fuselage to the wing.

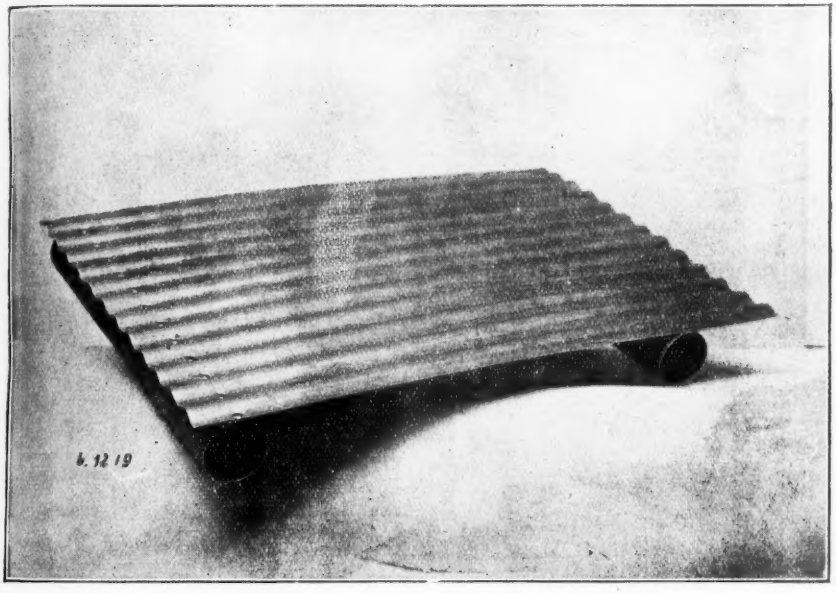

FIG. 35.—*Sample of corrugated plate cover to the spar.*

From a constructional standpoint, it is important to have the wing built as a solid unbroken structure, not interrupted by the fuselage, upon which structure the body is set directly, as in the low-decker, or to which it can be suspended, as in the parasol.

For the next aeroplane type, the pursuit single-seater J.7/J.9 (of 1917), I chose the arrangement of the low trim (Fig. 39). The middle part of the wing is developed into so-called "central framework," to which the part carrying the fuselage and the engine is immediately superposed. Such a central framework is represented in Fig. 40. The struts necessary in a "parasol" machine are here omitted, and by this means both air-resistance and weight are diminished. But the chief merit of the design lies in the safety ensured to the crew by the deep trim of the wings in case of bad landing and a damaged landing gear. The

wings are first to come in contact with the ground and absorb a great part of the shock. This behaviour of the machine has been observed in numerous instances.

The low trim of the wings was at the time of its first appearance a complete innovation, which in spite of its undoubted constructional merits had given rise to

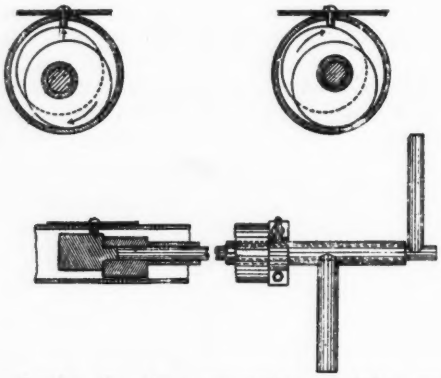

FIG. 36.—*Device for rivet connection of tubes and plates.*

strong objections. It was in particular contended that the high position of the centre of gravity might prove a cause of detrimental lateral instability, and flying the machine was at first considered a risky procedure. All such scruples were fully refuted by the success of the machine.

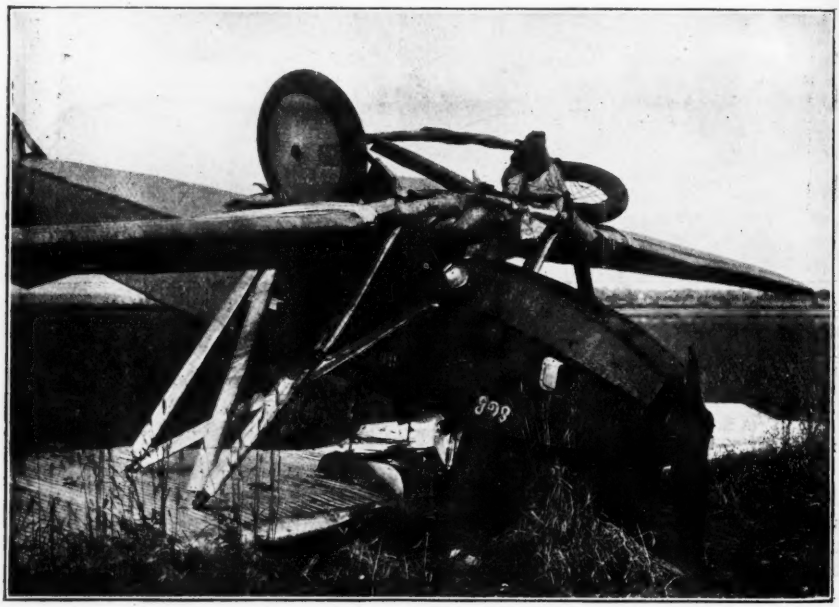

FIG. 37.—*Armoured box for J.4.*

The question had been broached, which of the two arrangements of the wings should be given the preference from the standpoint of aerodynamics—the parasol or the low wing trim.

My wind tunnel tests for the respective wings had first yielded results tallying with those lately published by the Göttingen Institute : that the trim of the wings

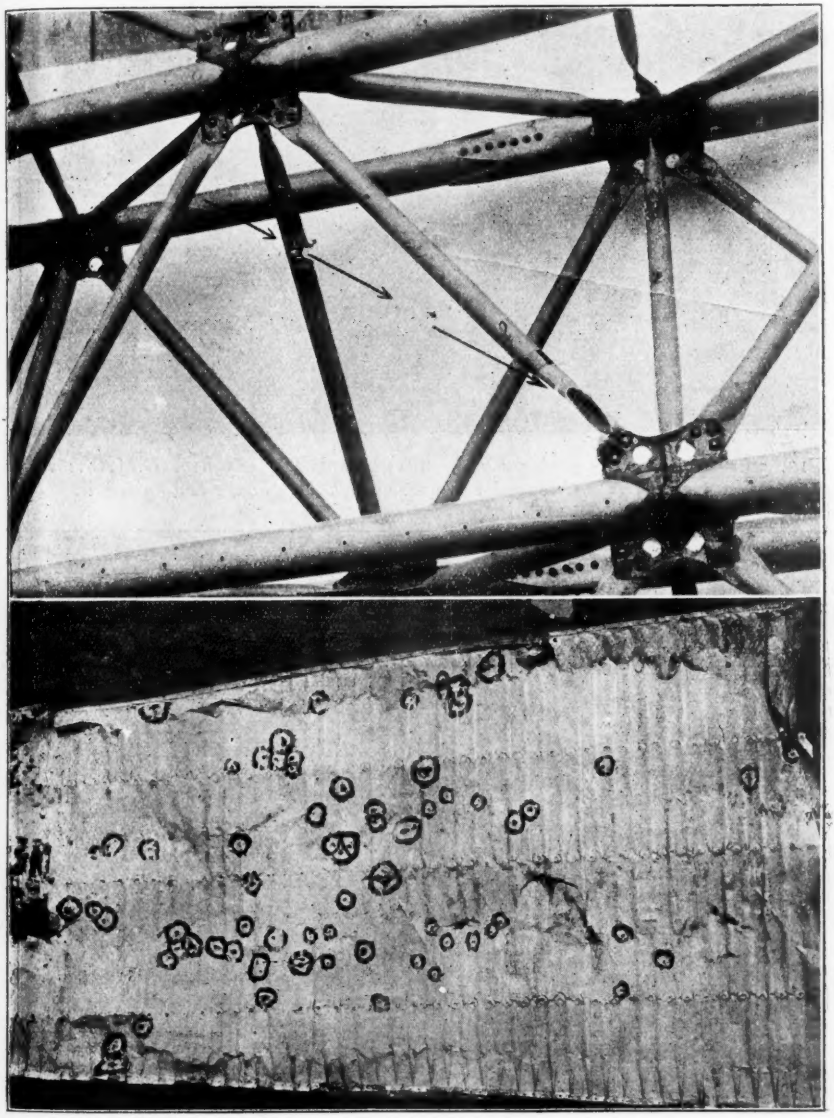

FIG. 38.—*Shots on J.4.*

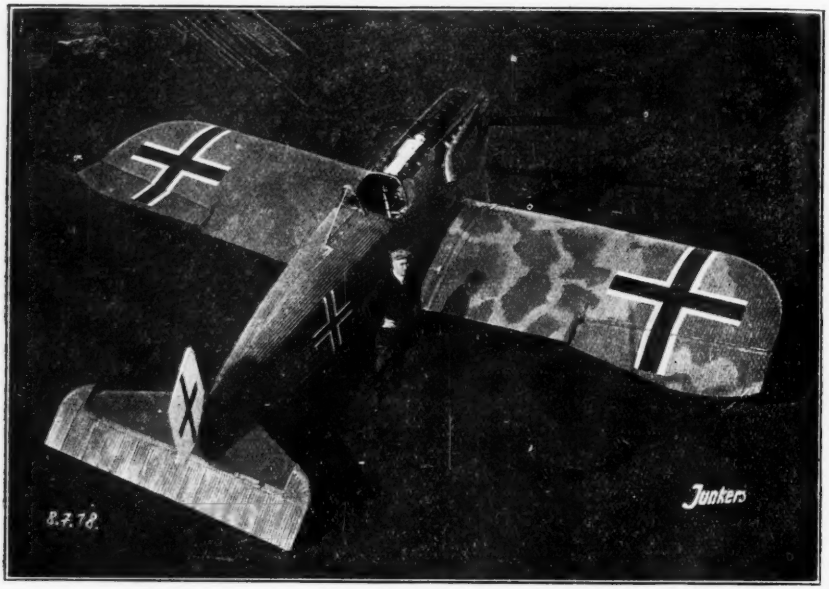

FIG. 39.—*Fighting one-seater J.7/J.9 (Junkers D.I.); 185 h.p. B.M.W.; service weight 835 kg.; speed 240 km. (150 E.M.)/hour; ceiling 6 km.*

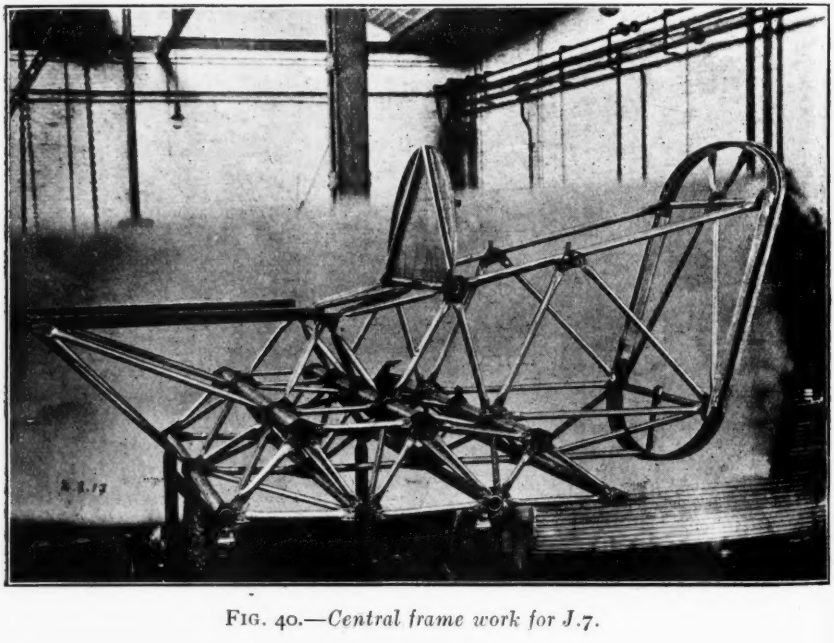

FIG. 40.—*Central frame work for J.7.*

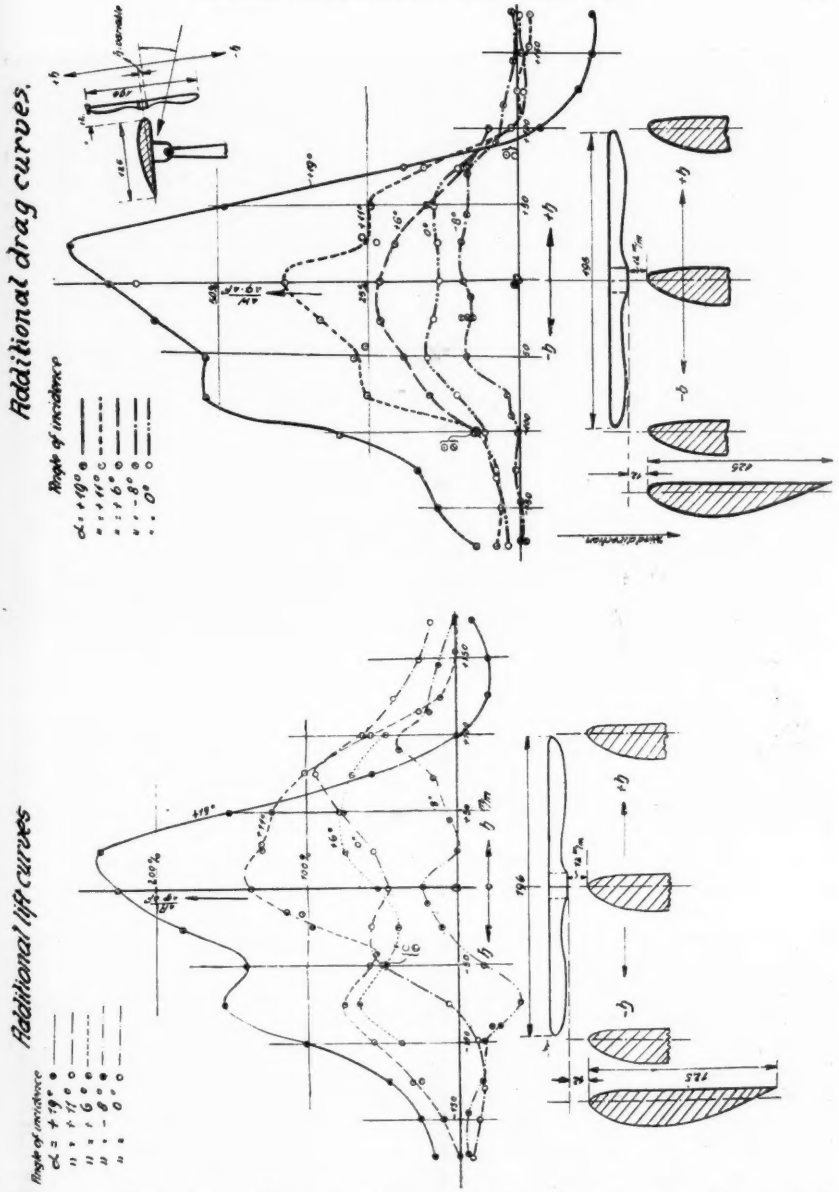

FIG. 41.—*Effect of propeller slip stream upon lift and drag. Variable vertical position of wing relative to propeller.* (Δ *F* = *O*, 125.0, 196 m² = *wing area influenced by slipstream*

q = *Dynamical pressure of wind*;
Δq = *thrust/prop. disc. area*; $9/\Delta 9 = \sim 3.6$;
ΔA = *Additional lift*
ΔW = *Additional drag* } *due to slip stream.*

above the body or level with its upper edge gives a better ratio lift-drag than the trim under the body. It is most useful, if the smooth run of the upper wing surface be not disturbed either by superstrictures or apertures. In this sense the parasol type has the advantage.

In subsequent experiments the effect of the propeller slipstream upon lift and drag has been considered. Fig. 41 shows such a test. We discern that the additional lift produced by the airscrew is higher when the screw is placed above the wing, and the additional drag lower. The same results were arrived at with other positions and sizes of the screw, particularly also with pusher propellers, likewise in the presence of a fuselage.

Later calculation shows that, especially with a very strong propeller slipstream,

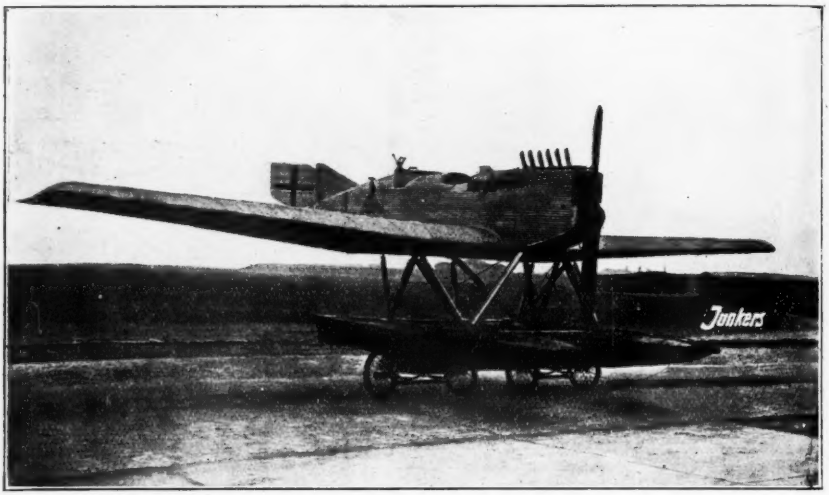

FIG. 42.—*Navy two-seater J.11: 185 h.p. Benz; service weight 1,420 kg.: supporting area 27 m²; speed 175 km. (108 E.M.)/hour; climb 3,000 m/26 min.*

i.e., in aeroplanes of very high engine power, the favourable influence above mentioned can compensate for the aerodynamical drawback of the high trim of the body.

Since then I have worked on both methods.

A two-seater quite similar to the J.7 was also produced, and later on changed into a hydroplane (Fig. 42) by the addition of floats. This was our first step in the development of the hydroplane.

The choice here made in favour of the two-float plane instead of the flying boat which is preferred abroad, came quite naturally since here the question was to progress as quickly as possible. It may be that from purely aerodynamic considerations the flying boat is superior, and that it also fulfils better our æsthetic requirement for a construction which forms an organic whole.

From the point of view of production, however, as well as of operation, the possibility of changing, at least for small and middle-sized types, a land aeroplane into a hydroplane by the simple substitution of floats for landing wheels and *vice versa*, is of first-rate importance. In case of damage the exchange of a float is also easily accomplished, while the flying boat must, for each repair, be removed

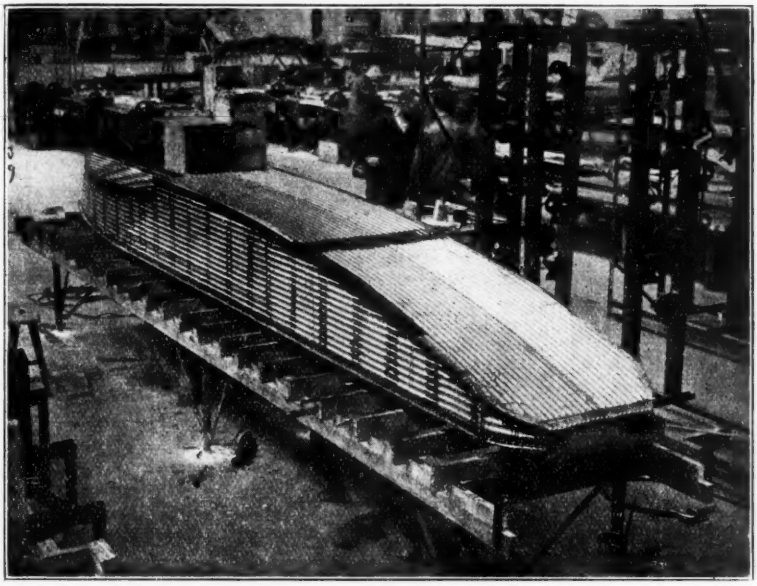

FIG. 43.—*Duraluminum float.*

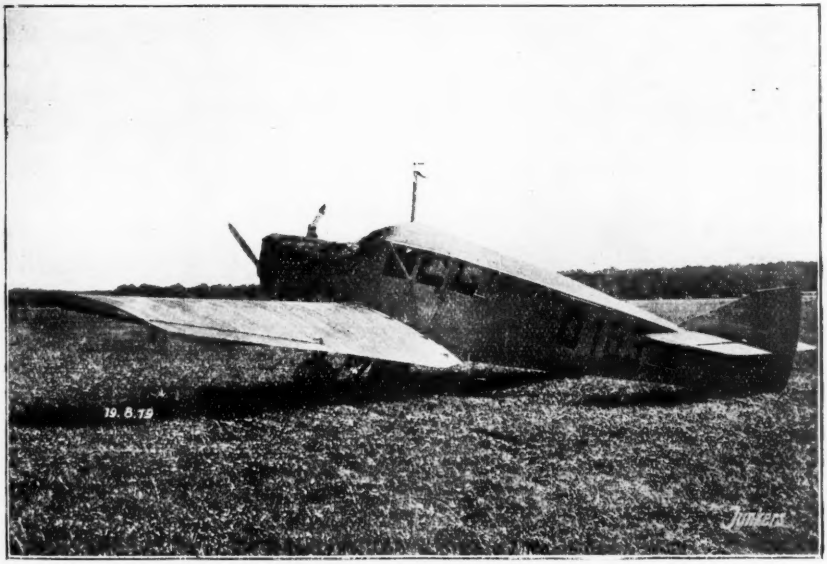

FIG. 44.—*Commercial aeroplane J.13; 185 h.p. B.M.W.; service weight normally 1,900 kg.; speed 165 km. (103 E.M.)/hour; climb 1,000 m/12 min.; supporting area 40 m².*

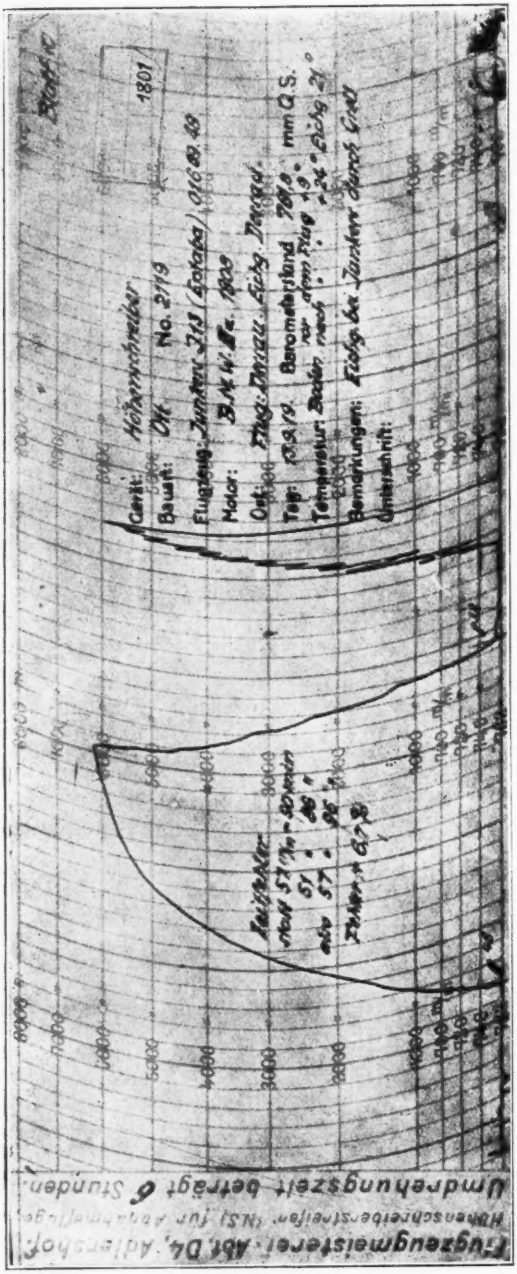

FIG. 45.—*Pressure registration of altitude record flight.*

from work for a longer space of time. As regards seaworthiness, the float plane is not in any sense inferior to the flying boat.

Our float aeroplanes have done very well in practical service, equally as concerns flying performance—I might quote here the results of the Tyrrhenic Cup Competition of Naples in 1922—or as regards resistance and excellent watertightness of the floats, manufactured of duralumin like the wings (Fig. 43).

J.7 was the last war aeroplane made by us. After the armistice we set up a programme for the construction of commercial aeroplanes. It comprised :—

A giant aeroplane of 740-1,000 h.p. ;
A middle-sized commercial machine of 160-185 h.p. ; and
A small type for the same purpose of 50-70 h.p.

The first one finished was the well-known commercial limousine six-seater, J.13 (Fig. 44). Its characteristic feature lies in the solution of the problem of

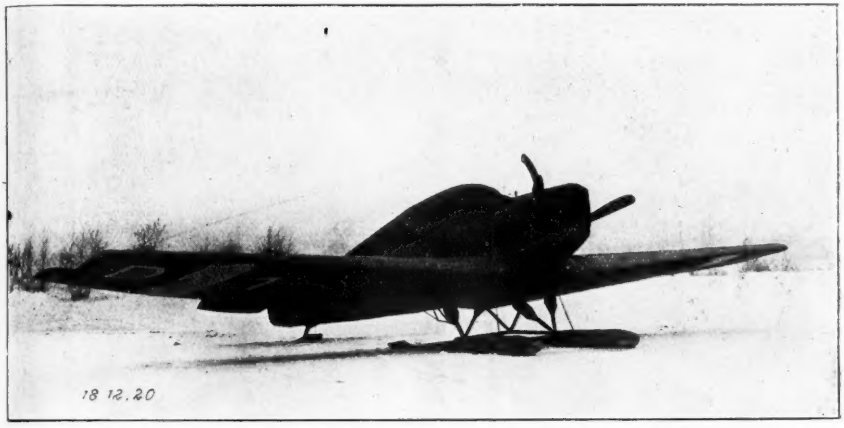

FIG. 46.—*Commercial J.13 on sledge runners.*

creating a large hollow space for the passengers and at the same time of achieving enormous progress in regard to economy.

The aeroplane showed already in its first longer flight, with a 160 h.p. Mercedes, the average speed of 165km./h. (102 miles), certainly a good performance for the low power. It also has on its record the flight of September 13th, 1919, when, with a 185 B.M.W. engine and eight persons (525kg. useful load, this figure not representing, however, the total amount of the available load of the machine), a ceiling of 6,750m. was reached in 86 minutes (reduced figures, 6,920m. in 81.6 minutes). The record is corroborated by a self-registering barometer, and officially entered (Fig. 45).

You might have heard that this commercial aeroplane has been used from tropical Columbia in South America up to the snow fields of Northern Canada and Finland. It has proved to be utterly satisfactory in all its principal features; the drawbacks, which became apparent, were easily removed.

When it first came out it was superior in economy to most of the types extant, even now it cannot be considered antiquated, and has proved fully able to compete when the prohibition against flying was abolished.

By the appliance of runners (Fig. 46) the machine has been adapted also

to starting and alighting on snow, and has been used successfully in this capacity; Amundsen has taken along such an aeroplane on his last Polar expedition.

J.13 has also done satisfactory work as a hydroplane, with attached floats (Fig 47). In this quality it also comes in consideration for use in the tropics, where the surface of the water frequently represents the only available landing place. So we have but recently had a report from the Sociedad Colombo Alemana de Transportes Aereos, in Columbia, according to which the regular air traffic of the Company with J.13 hydroplanes has gone on in 1922 without a single accident.

The small aeroplane was executed in two types. The one is a cabin aeroplane, J.16 (Fig. 48); most of you will be already acquainted with it by paragraphs in the papers. The second shape is that of an open aeroplane, J.19 (Fig. 49). Both are of the parasol type, the above mentioned aerodynamical superiority of which I could not well forego when account is taken of the low engine power.

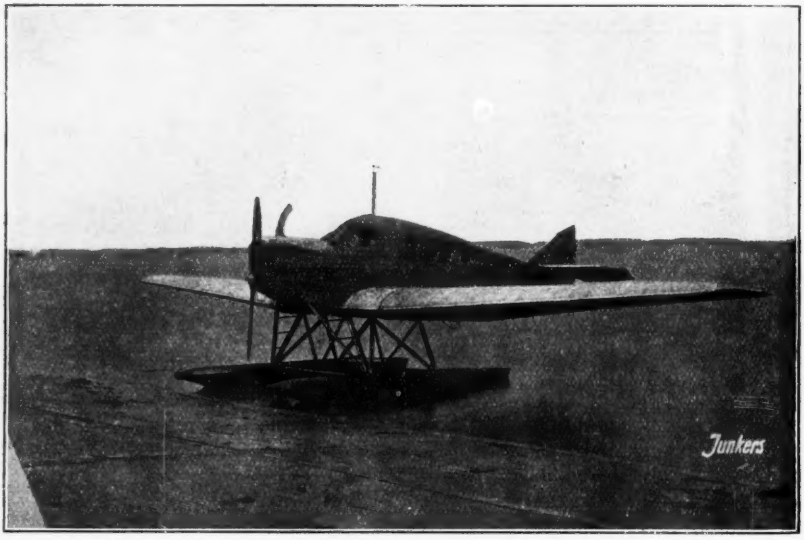

FIG. 47.—*Sea plane J.13.*

But the advantages of metal construction become relatively more pronounced in the large aeroplane than in the small one. Only in this case can the principle of locating within the wing all parts giving resistance, be carried out on a large scale. In my opinion the commercial aircraft of the future will be the fast giant aeroplane, and for this reason I have quite early begun the preparatory work towards the construction of such a craft. Fig. 50 shows the design of an "R" aeroplane of the year 1917, with an engine power of four times 260 h.p. It is a war machine. The engines are housed in the thick wing and readily accessible.

Fig. 51 presents a project, designed in 1918, of a flying boat of four times 1,000 h.p. The aspect ratio is here already distinctly higher than in the preceding design.

The engines provided for the last named giant plane are opposed-piston heavy oil engines, at the development of which I have been working for many years. In this case the horizontal arrangement would be particularly appropriate, as readily housed in the wing.

FIG. 48.—*Covered little commercial plane J.16.*

FIG. 49.—*Open little commercial plane J.19.*

My experience in engine construction has satisfied me that the heavy oil engine is especially fitted for the aeroplane. Setting aside the greater economy and less danger from fire, in which qualities the heavy oil engine forms a necessary complement of the metal aeroplane, it is also more reliable in operation and easier to control than the carburettor motor. It is therefore also more fit to be developed than the last named, and I hope that my engine factory will be able to contribute to its evolution in the direction determined upon.

Not a single one of the named giant plane projects has so far been constructed, owing to the clauses of the Peace Treaty, *i.e.*, on account of the great risk caused by the uncertainty in the interpretation and execution of these clauses. The building of a large aeroplane, meant as a precursor to the giant craft (Fig. 52 shows the assemblage of it, and Fig. 53 part of the wings), has been stopped since 1921 for these reasons.

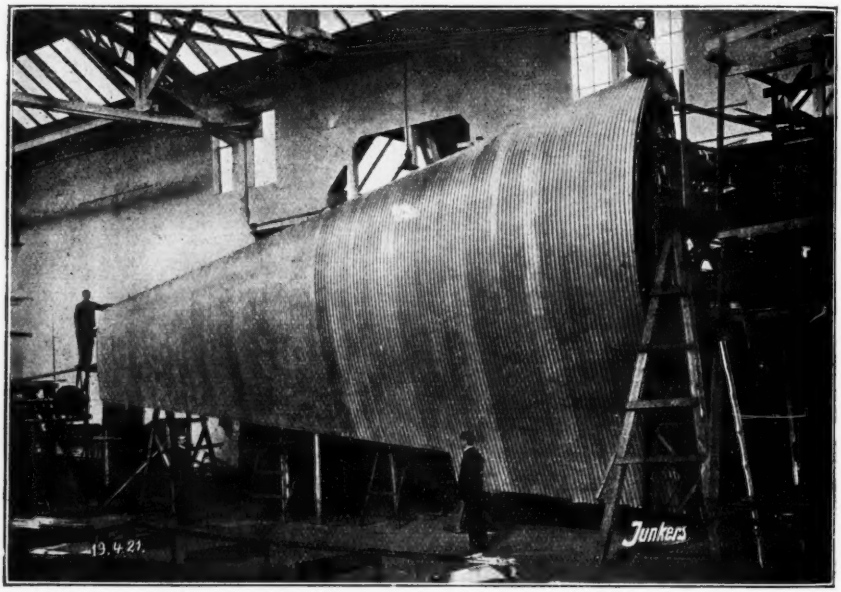

FIG. 53.—*Part of wing of the large plane J.G.1.*

In recent times the work on giant planes has to be confined to occasional but certainly valuable preparatory studies, and the development of detached parts, this work representing, however, very useful material for a subsequent swift and safe construction of giant aeroplanes in metal.

Whether this prohibition of the construction of giant planes, due to political scruples, is in the interest of the nations foremost in civilisation is a question not to be discussed here. At any rate those nations whose widespread colonies render a fast means of communication highly desirable within their confines as well as with one another and the mother country, will certainly be most interested in the development of the aeroplane, the quickest of all vehicles.

What enormous advance there is yet in store for aviation, cannot be doubted by anybody who examines the possibilities of aeroplane construction and applica-

tion with the unprejudiced judgment of an expert; he cannot help but acquire the conviction that air travel will not be inferior in extent and importance to railway and shipping.

May aeronautics have the good fortune that England, which has accomplished pioneer work in navigation and railway construction, and which has also furnished such important contributions to the scientific, experimental and constructional branches of this, our latest province of communications, that this England will lend its powerful and active assistance to the furtherance of such lofty aims in free competition with all the nations of the globe.

AERIAL NAVIGATION

BY A. P. ROWE, A.R.C.S., D.I.C., B.SC.

(*Awarded Pilcher Memorial Prize*).

The motives prompting the desirability of human flight from the legendary period to the present time have been very numerous. For the last two hundred years, apart from the war period, we may reasonably assume that the predominant factor has been the rapid transport of personnel or material from one point to another. With this aspect of aviation, aerial navigation is intimately concerned. I want you at the outset to distinguish clearly between the problem of aerial navigation over comparatively short routes—such as from London to Paris—and what is surely the true realm of aircraft, the long distance flights from England to America, India and Australia. In favourable weather the European routes require no more of the pilot than that he should be able to read a map with what, for want of a better term, I will call aeronautical intelligence.

It is not with this mode of navigation that I propose to deal, but rather with the art of navigating a craft over

(1) Land which is unknown to the navigator;

(2) Land which, by reason of its nature, is not capable of being mapped, *e.g.*, desert;

(3) Large areas of water;

(4) Land or sea, but above clouds, such that the pilot may take advantage of favourable weather conditions, or, in time of war, may proceed to his object of attack without interference from A.A. fire.

This is the real problem of navigation, and I propose giving a short account of the various methods by which aircraft may be navigated under these conditions. As I proceed, I hope to differentiate between those methods which will be used when definite trans-Atlantic and similar air services have been established, and those with which the civil aviation pilot is at present more intimately concerned.

Dead Reckoning Navigation

Navigation by dead reckoning (D.R.) is essentially a question of geometry. Provided that the navigator can keep an accurate record of his ground speed and direction, then his position may be read off from his chart at any time. The problem in still air is, therefore, a simple one. Unfortunately, we have to consider the effect of wind just as the maritime navigator has to consider tides, and the problem becomes more complicated.

In still air, it is sufficient to take readings of an accurate compass and an air-speed indicator. We may extend the method to navigating in a wind by the addition of either a drift indicator, giving the angle between the course steered and the course made good, or by arranging a timing scale, used in conjunction with the altimeter, enabling the ground speed to be determined. In practice, the observer's instrument may conveniently combine these two factors. The speed and direction of the wind may then be determined by observing drift or taking a ground speed observation on two different courses, preferably separated by a fairly large angle, or, without changing course, by taking one drift and one timing observation. Probably the most convenient instrument for the use of the observer is the Wimperis wind gauge bearing plate (Fig. 1) in which drift is measured by tail bearings, either of a ground object or of a flare dropped into

the sea. The wind speed and direction may be read directly from the instrument. It is important that the principle upon which this instrument is constructed should be fully appreciated. Consider a horizontal bearing plate having a transparent centre as shown in Fig. 2.

Let A-C represent the direction of the fore and aft axis of the machine, and let a rod pivoted at A be laid across the bearing plate, such that A-B is parallel to the direction of drift of the ground. Let the bearing plate be oriented correctly and a line A-B drawn across it. If now this procedure is repeated on a number

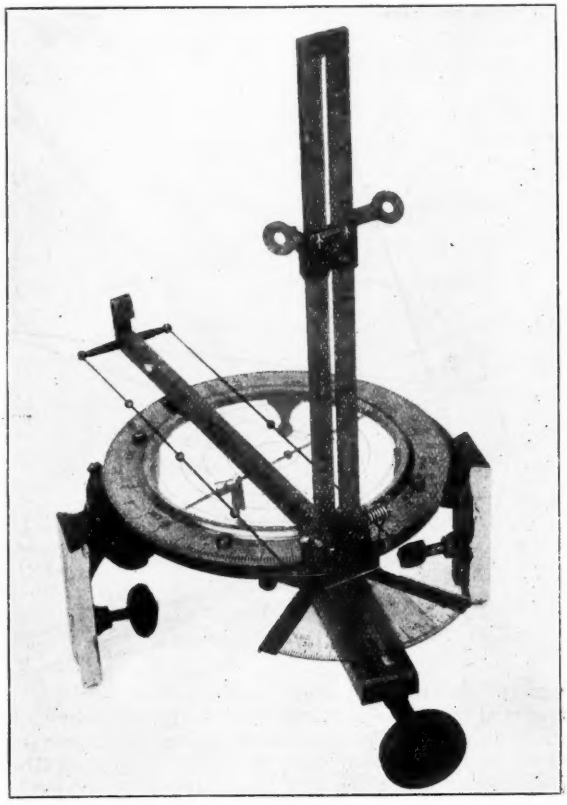

FIG. 1.

of courses, a wind star is obtained. The length P-C will then give the wind velocity to scale and the wind direction may be read off from the scale on the bearing plate. The point P may be obtained, of course, with two lines only, but it is obviously preferable to have at least a third and then to take the mean point of the resultant "cocked hat." As already indicated, if it is not desired to change course an observation of ground speed may be made and the point P in Fig. 1 located, such that A-P represents the observed ground speed.

It is sometimes convenient to take forward observations of drift, and for this purpose the Wimperis course setting sight may be employed. The instrument, shown in Fig. 3, employs the vector triangle principle described above.

It is necessary, however, to provide means enabling a pilot to navigate his machine by D.R. without the aid of an observer. The method must be such that observations are easily made, and that their reduction is simple in the extreme.

An American suggestion developed in England by Flight Lieutenant Capon consists of marking the wings with lines representing drift. The pilot sights some ground object ahead and has then only to watch the object until it crosses the marked wings, when the drift angle may be read off. If this is repeated for one other course, the wind speed and direction may be reduced by means of a course and distance calculator, or other simple device. Another simple method for the use of the pilot has been suggested by Mr. Wimperis, but has not yet been

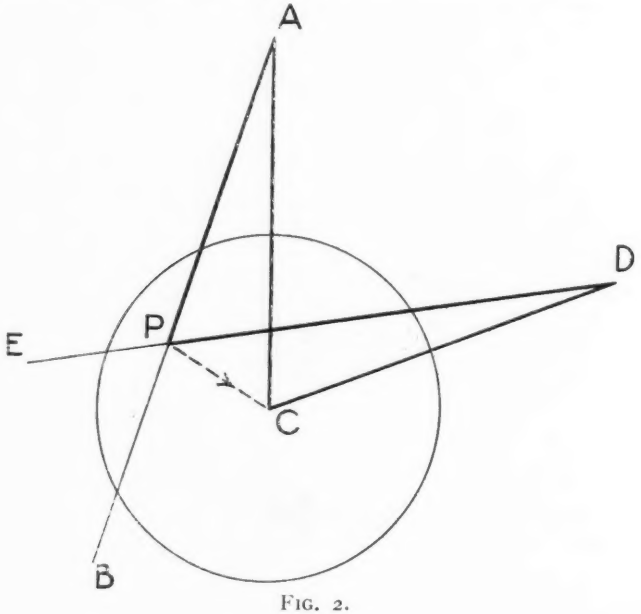

FIG. 2.

tried. It is proposed that the pilot should emit a puff of smoke from his machine when above a sighted ground object, and then fly in any manner he chooses for a measured period T, obtained by stop-watch timing, and to arrange that at the end of this period he is coincident with the puff of smoke and heading toward the ground object above which the puff was emitted. Suppose he reaches the ground object in time t, then the course steered toward the object obviously gives the wind direction and the wind speed is given by

$$\text{Wind speed} = \text{air speed } \{ t/(T+t) \}$$

These methods of enabling a pilot to determine the character of the wind involve the sacrifice of a certain amount of accuracy, but the former is likely to be of great use to civilian pilots at this stage of aeronautical development. The second method has not yet been used.

We have seen, therefore, that as long as it is possible to take the drift of the machine with respect to a ground object, the wind speed and direction may be satisfactorily determined. The methods described allow of an accuracy of about 5 per cent. of the wind velocity, and the wind direction can be estimated to within two degrees.

Astronomical Observations

I will now go on to the question of navigation by astronomical observation. This method is, perhaps, of little use at the present time, but for long distance flights of the future it will be a necessity. I want you to note particularly that D.R. records should always be kept as the flight progresses. If above cloud, and drift observations are unable to be taken, the meteorological forecast must be accepted, or if the latter is not available, then the nature of the wind observed at the last drift observation must be assumed to have continued, unless the pilot or observer has reason to believe that a change has occurred.

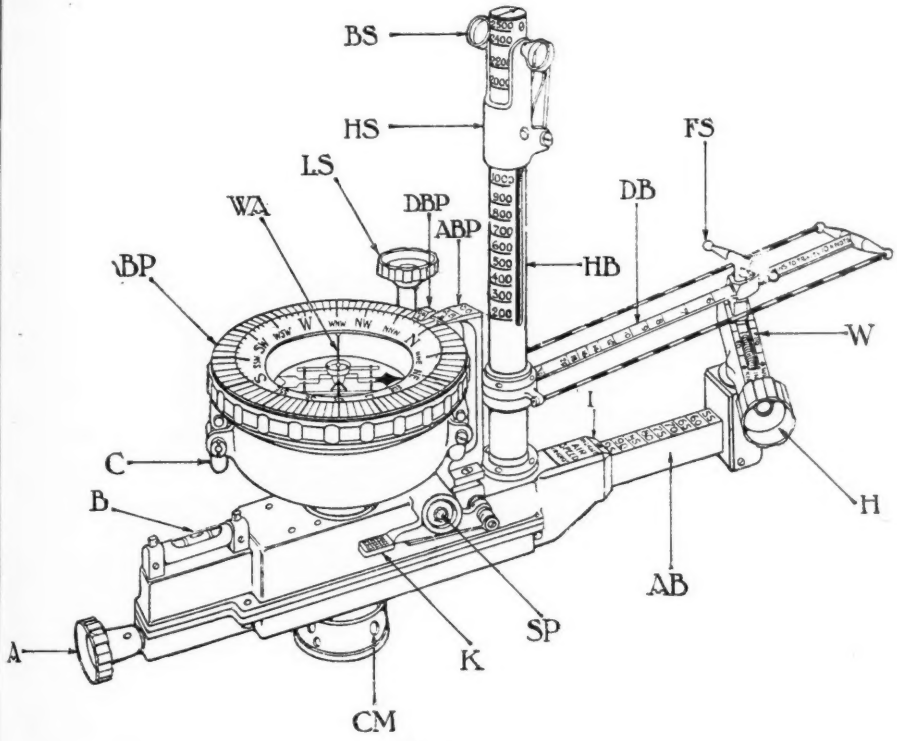

FIG. 3.

Astronomical observations serve only as a check on D.R. calculations. The basic principle underlying this type of navigation is a simple one. If the maritime navigator is able to take bearings of two lightships (*i.e.*, two positions fixed relative to the earth) then his position is known definitely. In the same way, the air navigator can determine his position from observation of two objects which are fixed relative to the earth. The place on the earth's surface immediately beneath a given heavenly body is called the "geographical position" of that body, and at a given time on a given day such a body may be regarded as being fixed relative to the earth. One astronomical observation allows a position line to be drawn upon the navigator's chart. Such an observation necessitates the use of a sextant, a chronometer keeping Greenwich mean time (G.M.T.) and a nautical almanac. Two astronomical observations, giving two position lines

cutting at an angle, obviously locates the navigator's position definitely. For example, an observation that the altitude was 60° would show that the observer was at some point on a circle, the centre of which was the geographical position of the heavenly body and the radius was 30° (*i.e.*, 1,800 nautical miles). His D.R. record, however, enables him to choose that part of the circle in which he is interested and it is sufficiently accurate to draw a straight line on his chart, this line being a tangent to the circle. The direction it takes on the map is obviously at right angles to the line joining the geographical position of the heavenly body to the observer's position, *i.e.*, at right angles to the azimuth of the heavenly body at the instant it was observed.

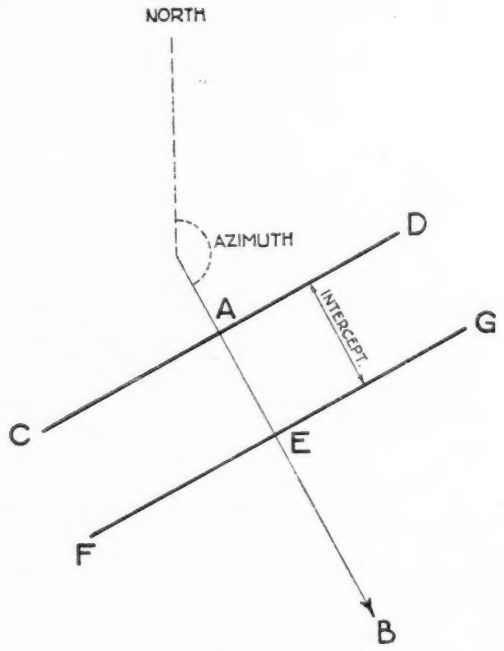

FIG. 4.

The position line is obtained in the following manner. The zenith distance and the azimuth of an observed heavenly body are calculated for the D.R. position of the aircraft, and the time noted. Let A-B (Fig. 4) represent the computed azimuth line drawn from A, the D.R. position. Then if the observed zenith distance is equal to the calculated distance, C-D is the position line. If, however, the observed zenith distance is greater or less than the calculated value, a line such as F-G is drawn parallel to C-D, the distance A-E representing in nautical miles the observed difference in minutes of arc. At least two position lines are necessary to determine the position of the observer. If it were possible to measure the azimuth as well as the altitude of any heavenly body, then a " fix " could be obtained by these two observations of the one body. In practice, however, it is necessary to make observations of the altitude of two heavenly bodies at the same time, or of one forenoon and one afternoon observation of the sun, estimating the run between the observations by D.R. methods. If, however, one directional wireless observation is possible, this allows one position line to be drawn and one

observation of the altitude of any heavenly body would then allow a "fix" to be obtained.

Observations of altitude are, of course, made with a sextant, and the design of a suitable model has been the subject of much patient research. The naval pattern sextant used for determining altitude at sea depends for its use upon the existence of a definite horizon, whether sea or haze. The air navigator cannot depend upon the existence of such an horizon, and even if one is visible, it is necessary to make a correction for "dip," depending upon the altitude of the observer. The value of this correction in minutes of arc is approximately equal to the square root of the observer's height in feet. If an observation is taken on a cloud horizon, it is necessary to know the height of the cloud, and this gives

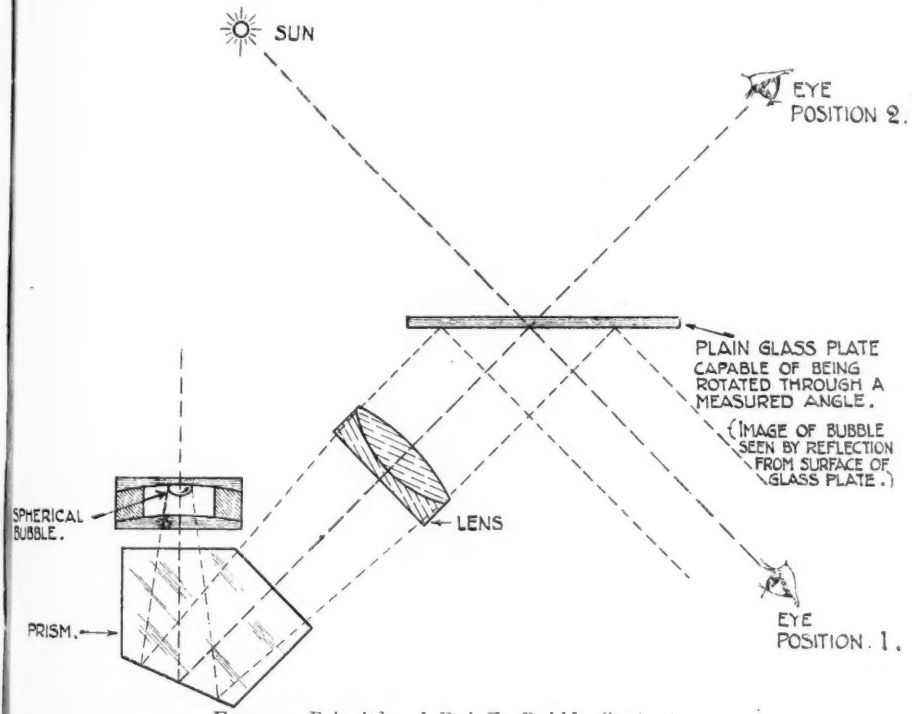
SUN
EYE POSITION 2.
PLAIN GLASS PLATE CAPABLE OF BEING ROTATED THROUGH A MEASURED ANGLE.
(IMAGE OF BUBBLE SEEN BY REFLECTION FROM SURFACE OF GLASS PLATE.)
SPHERICAL BUBBLE.
LENS
PRISM.
EYE POSITION. 1.

FIG. 5.—*Principle of R.A.E. Bubble Sextant.*

rise to errors. The Baker and Hughes cloud horizon sextant was an attempt to get over this difficulty. Images of two diametrically opposite portions of the horizon are projected into the field of view; then the true vertical should lie midway between the two images. An image of the sun is then made to appear midway between the two horizon images. It cannot, however, be assumed that the two positions of the horizon are at the same height, and error may well arise from this cause. Moreover, this sextant, like the naval pattern sextant, can only be used during the day, and has therefore a limited use. The R.A.E. bubble sextant, which we shall next consider, overcomes this difficulty by employing an artificial horizon. The principle of this instrument is shown in Fig. 5. The vertical is indicated by a vapour bubble constrained to move in contact with a spherical surface, the radius of curvature of which is equal to the focal length of the

collimating lens. If the instrument is rocked in the hand the bubble will appear to move with the astronomical body under observation. This is a great advantage, but errors due to small accelerations acting on the bubble are still existent. The spherical level is illuminated for and the instrument can therefore be used under all circumstances and is much in advance of other sextants for aircraft use.

It has been stated that it is necessary to compare the observed altitude with the altitude calculated from the D.R. position and the time of the observation. The methods employed at sea for this calculation are not suitable for use in the air, and moreover give a greater accuracy than necessary for our purpose. The reduction of observations in the air has to be performed quickly and with but little

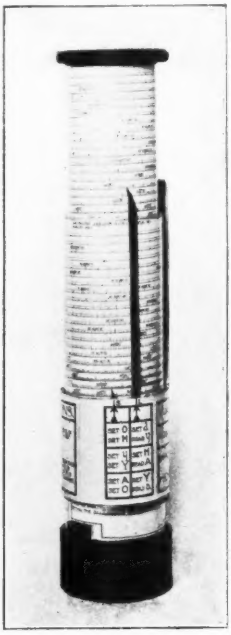

FIG. 6.

available space. The most convenient methods are either graphical—the most important of which is the Veater diagram—or by use of a slide rule. The Bygrave slide rule is shown in Fig. 6. The astronomical triangle is solved by dividing it into two right angled spherical triangles. The instrument occupies but little space, is rapid in use and gives a degree of accuracy comparing favourably with other methods.

In addition, certain calculating machines have been devised, notably the Baker navigation machine, which is a combination of a mechanical and graphical method.

Directional Wireless

We have next to consider the navigation of aircraft by directional wireless. This method is comparativey recent and has not yet been satisfactorily developed. The basic principle is a simple one. If a coil A B C D (Fig. 7) is placed on the path

of wireless waves, such that the direction of propagation is parallel to B-C, then oscillating currents of different intensities will be set up in A-B and C-D. If now the coil is turned through 90 degrees, no current flows through it. Once, therefore, a search coil of this kind is mounted on a vertical axis it can be turned until the current received is either a maximum or a minimum and the direction of the wireless waves will be indicated. In practice it is general to observe the minimum current rather than the maximum current. With this simple form, of course, little accuracy can be expected, but the introduction of auxiliary electrical detecting apparatus enables the direction to be found to within a degree or two.

There are two alternative methods of use. In one, the aircraft carries the receiving apparatus, and notes the direction in which the wireless waves appear to come from a sending or beacon station, the actual position of which is known.

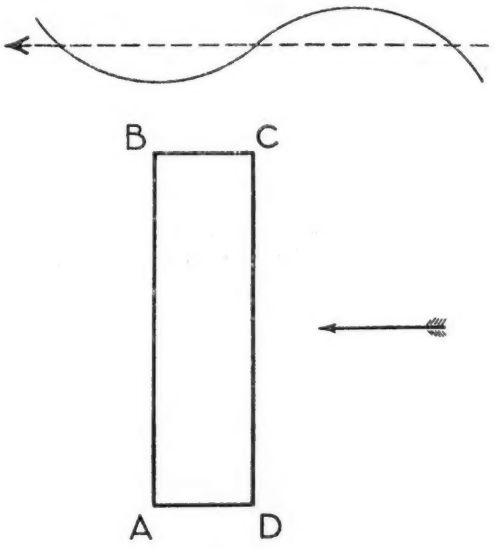

FIG. 7.

This method has the advantage of secrecy and, moreover, gives less work to the stations. The other method consists in calling up the beacon stations within range, and any two of these acting in collaboration can determine the position of the aircraft. Whichever method is adopted, there is a correction to be made when plotting a position line on a Mercator chart, owing to the fact that the wireless waves follow a great circle, and not the rhumb line on the chart. This correction may be made either by the Weir Azimuth diagram, or by the conversion angle method, the latter being sufficiently accurate for distances up to 1,000 miles.

The conversion angle is given by

(Half the difference of longitude of the sending and receiving station) × (Sine of mean latitude),

and is approximately the angle between the rhumb line and the great circle through the two stations.

Before concluding, I should like to call your attention to a problem intimately connected with ordinary navigation. I refer to the guiding and landing of the

aeroplane in a fog. This at present constitutes one of the chief dangers of civil aviation, and the climate of England, particularly Kent, being what it is, we cannot afford to ignore it. The gyro turn indicator, an instrument recording departure from the horizontal, is being developed and may be expected to form part of the standard equipment of an aeroplane in the near future. No system of landing in fogs has yet been perfected, however, and I will merely state that the problem is being attacked in two directions. One consists of locating a source of sound on the aerodrome, and the other, a French method, arranges for the guidance of aircraft by the electrical field produced by cables laid along the ground.

I hope I have shown that the science of navigation has progressed, at least as far, as other branches of aeronautics. When the time comes for the establishment of regular trans-Atlantic services, as come it will, I have no doubt that the navigation of the craft will be simply a matter of training observers to use their instruments intelligently. That time is not yet, but we, who probably represent the first generation to commence with the fixed object of making aeronautics our life's study, must prepare for it. To say that the Australian and Atlantic flights have been accomplished with an element of chance is not to depreciate the wonderful efforts of those responsible; rather is it to emphasise their courage. But the future of civil aviation cannot be expected to rest upon the courage of passengers. The business man of the future, travelling by air to America, has a right to ignore the risk exactly as he does to-day when considering a train journey. It is toward that goal that we must concentrate our endeavours.

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AVIATION IN SOUTH AMERICA, WITH AN INTRODUCTION ON THE SOUTH ATLANTIC FLIGHT.

A Paper read before the Royal Aeronautical Society (Scottish Branch) on 7th March, 1923,

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The object of this lecture is to try and show you what has been done, and what is still to do, in aviation on the South American continent, and I therefore propose to marshal my subject under the following headings :—

1. Existing air services.
2. New air routes projected.
3. Prospect of running aeroplane or seaplane services for mail or passenger traffic.
4. Missions from foreign countries.
5. Aviation transport companies.

Under these headings I will deal with the countries in rotation as I visited them, *i.e.* :—

Brazil,	Chili,
Uruguay,	Peru and
Argentine,	Colombia.

But, before dealing with the main subject, I think it would be fitting, rather than jump directly from this country to Brazil, to take you there by stages through the air and describe briefly that most wonderful flight made from Portugal to Brazil by those two great aviators of the Portuguese Navy, Comm. Sacaduro Cabral and Capt. Gago Coutinho.

These were not young enthusiasts that had set out to brave the wind and wave of the South Atlantic, but veterans in age as well as war, the sum of their ages aggregating more than a century.

If anything should go wrong, they could not count on a relay of warships to save them from disaster, as was the case with Read in 1919. They had to trust to their own skill and to luck. Coutinho had invented a modified type of sextant for taking observations in flight without recourse to the sea level horizon —a device entirely new in aeronautics, and one that proved to be a God-send to them in their navigation over those waste waters.

It was on March 30th, 1922, that these two intrepid men set out from Lisbon in their caravel of the air—a Fairey Series III. seaplane with 360 h.p. Rolls-Royce engine, carrying a useful load of 3,100 lbs., including fuel for 18 hours, having a speed with full load of 83 knots.

The route they intended to follow will be seen on the map to be from Lisbon to Las Palmas, Canary Islands, 710 miles; thence to Cape Verde Islands, 816 miles; thence to St. Paul's Rocks, 900 miles; thence to Fernando Noronha, 490 miles; and finally to Pernambuco, 275 miles, representing a total of 3,191 miles entirely over sea.

All went well on the first stretch to Las Palmas, which was accomplished in 7¼ hours, they having flown steadily at the rate of just under 100 miles per hour.

Waiting for a good moon, they launched into the unknown for Cape Verde Islands, and for more than half the way they were buffeted by high winds and

the vibration of the engine threw the compass out of order, so that they had to steer their course almost entirely by the sun. Only one steamer was seen—a mere smudge of smoke labouring far to the south on the bosom of the heaving waters. At last St. Vincent loomed ahead, where a good landing was made and a much-needed rest taken.

Rough weather delayed the start on the next stage, the most difficult of all, that from St. Vincent to those silent sentinels of the South Atlantic, the St. Paul's Rocks. The flight was made successfully, a distance of 900 miles, but on arrival misfortune overtook the gallant airmen, and they wrecked their machine in landing on a heavy sea. Another machine was cabled for from Portugal, and they took delivery of this machine at Fernando Noronha, and then started back to circle the St. Paul's Rocks and return to Fernando Noronha, so that the flight should be complete. Alas! misfortune still dogged their efforts, for in this attempt they were blown by a gale far out of their course and at last had to come down in the rough sea. They were rescued by the British steamer "Paris."

Another machine was sent out, and finally, on June 5th, the final stage from Fernando Noronha to Pernambuco was accomplished. And so Commander Sacaduro Cabral arrived by air where just 422 years before another of his race and name, Pedro Alvarez Cabral, arrived by sea and founded an Empire for King Manoel and Portugal.

The navigating skill displayed on this flight may have been equalled, but certainly has never been surpassed, the powers of endurance and courage by these veterans, the one 49 and the other 54 years of age, being beyond all praise.

Any one of the first three non-stop flights was in itself a notable achievement, but the three together constitute a monument to man's conquest over the elements. That the machines and engines were all British adds another well-deserved tribute to the excellency of workmanship and material supplied by the British aircraft constructor.

On arrival in Rio de Janeiro, to which city the airmen continued their flight, they were presented with a cheque for £10,000 entirely raised by public subscription, and it is understood that this money is being spent by them in the purchase of a new machine, this time of Italian construction, with which to repeat their exploit early in the spring. Let us hope that they will be even more successful in this second attempt than they were in the first.

Brazil

And now, having brought you so far by air, I will turn to the main theme of my lecture.

Brazil, which is the largest of the South American Republics, has a population of over 30 millions and an area of 3,291,416 square miles, and is the fourth largest country in the world. Brazil has had a close connection with aviation since its earliest inception, for on November 12th, 1906, Santos Dumont, in France, astonished the world by making what was then an unparalleled duration record of 21 seconds. That was only sixteen years ago. To-day Brazil has a well-trained naval and military Air Force, each operated separately, amounting to some ten squadrons in all, the naval side being trained by the Americans and the military by the French. Naturally, the machines in use are either American or French, the Navy having mainly Curtiss flying boats, and the Army, Hanriot, Spad, Farman, Morane Saulnier, and some obsolete Nieuports and Caudrons. There are naval schools in Rio de Janeiro and Porto Alegre, and a military school at Sao Paulo, and others are to be established as soon as the finances of the country permit.

Of commercial services there are actually none, but two semi-commercial routes are projected from Rio to Porto Alegre, the one along the coast touching at

Santos, Paranaqua and S. Miguel, and the inland one calling at Sao Paulo, Curitiba and Camizas. These services at the present are intended primarily for use of the naval and military forces, and will be organised and controlled by the Ministry of Marine and Ministry of War respectively, but the facilities they afford will be available for civil and postal purposes. The Government is authorised to borrow up to 4,000 centos of milreis, or £200,000, to cover the cost of the two schemes.

A passenger and freight service between Porto Alegre and Montevideo, Uruguay, serving various centres between these two ports, was projected by a Senor Abreu Scareo, and he endeavoured to form a company for this purpose, but financial support was lacking, so the project fell through.

The prospects for running aeroplane or flying boat services for mail and passenger traffic are fairly good, inasmuch as there is extensive territory not served by railroads, and the coastal boat service between the smaller ports is uncomfortable and irregular, but drawbacks would be found in the difficulty of transporting material and petrol to outlying aerodromes, and in the unsuitability of the ground traversed for forced landings.

The only foreign missions are those already mentioned, *i.e.*, the United States Mission for training the Navy and Naval Air Service, and the French Mission for training the Army and Military Air Service. During the centenary celebrations, Capt. René Fonck and Lieut. Fronval came out to Rio on a special mission of aeronautical propaganda, chiefly in the interest of the French aircraft constructors. They had with them four aeroplanes—two of a commercial type—Breguets—and two fast Spads. I witnessed one of the finest exhibitions of acrobatic flying I have ever seen, and was only one of 200,000 people that saw it. It took me 2¾ hours in the car to do three miles back from the racecourse to my hotel—the traffic was so thick. Thus do the French Government help their aircraft industry.

Joy-riding is carried on to a small extent by Orten Hoover, an American, at Rio, and Mlle. Boland, of trans-Andes fame, runs a ferry service from Rio across the Bay to Nichteroy—a distance of 6½ miles.

Apart from the Military School of Guapira already mentioned, there are four other civil schools in the Sao Paulo district which train pilots for the Army under contract from the Ministry of War. They are :—

Escola da Forca Publica, using Curtiss Oriole machines.
Escola Campineira, using Caudron machines.
Escola Curtiss (run by orten Hoover), using Curtiss machines.
Escola Brazil, using Aviatic machines.

The foregoing represents the extent of aerial activities in Brazil as they are to-day, and it seems to me lamentable that Britain, who led the world in aviation during the war, should have no place in the training of, or in the supply of material to, Brazil, which undoubtedly will be in a very few years the greatest, richest and most powerful of all the South American Republics.

Uruguay

Uruguay, with a population of only a million and a half, and an area of 72,210 square miles, is the smallest of all the South American Republics. Actually there is no Air Service, either naval or military, that could be called as such, but the Army possesses a few obsolete British and French machines, mainly used for training purposes, the purchase of the former being the result of good pioneering work done by Major Scott, an ex-R.A.F. officer, on an Avro machine in 1919.

There is a military aviation school near Montevideo, and the head of this school has just returned from a mission to France, where he purchased six new Nieuports and a quantity of spare parts to the total value of half a million francs.

This may not seem a great deal, but as their standing Army only amounts to 10,000 officers and men, it is sufficient to form the nucleus of an efficient military Air Service.

An Air Convention has been signed between the Uruguayan and Argentine Governments regulating the traffic between the two capitals, and the negotiations between the postal authorities of the two countries have been brought to a satisfactory conclusion. On the first trip from Buenos Aires to Montevideo, after the completion of the negotiations, 1,270 letters were carried. I will deal, however, further with this cross-river service under the heading of the Argentine, to which it properly belongs, as the initative is all from that side.

The possibilities of successfully running aeroplane or seaplane services in Uruguay itself for mail or passenger traffic are not good. The railway and telegraph communications with the interior are admittedly bad, but on the other hand, the population in the country districts is scanty, for out of the total population of 1,500,000, a third of this is in Montevideo itself.

An international service from Montevideo to Asuncion, the capital of Uruguay, with halts at Colonia (Uruguay), Parana (Argentine), Corriantes (Argentine) and Formosa (Paraguay), might be a paying proposition for the future, though ambitious, I admit.

There have been no definite aviation missions to Uruguay, though in 1919 the French and Italian Missions to the Argentine gave exhibition flights. The Army, however, is trained on French lines, and the uniforms are almost identical with those seen in France in pre-war days, so that it can be taken that the predominating influence is French.

There are no aviation transport companies in existence yet, but tentative schemes for a service to Buenos Aires, and another to Rio Grande del Sul and Porto Alegre, have been mooted from time to time, though nothing has so far matured.

From the foregoing you will realise that there is not much being done in Uruguay in aviation, and the prospects for the future are somewhat obscure.

Argentine

The Argentine Republic is the second largest in South America, and has a population of 9,500,000, of which 2,275,000 are to be found in the province of Buenos Aires.

Great enthusiasm was shown during 1919 and 1920 in aviation generally, but in 1921 this dwindled somewhat, owing chiefly to the general crisis which swept the country, and also to the failure of the French and Italian Missions to weather the storm.

1922 saw a recrudescence of interest, due mainly to the initative of the Army aviation authorities, who put forward a scheme for the establishment of air routes throughout the Republic. The hub of these services was to be at the military aerodrome of El Palomar, the spokes leading to outlying stations to be created at Monte Caseres, Rosario, Salta, Cordoba, Mendoza, Nouquen and Callegos, besides which 22 secondary stations and 126 emergency landing grounds were projected. The negotiations between the Ministry of War, the Postal Department and the Ministry of Commerce in regard to this project were still in progress at the time of my departure.

Military aviation has made great progress, being well organised and equipped with modern craft. The training at El Palomar is most efficiently carried out, and real merit is to be found among the instructing officers and pilots. I would like to mention specially Captains Zanni and Parodi, two of Argentine's most capable pioneers, who, by their enthusiasm and example, have done much to vulgarise aviation in their country. They were among the first and few pilots

who successfully flew the Cordillera de los Andes to Chili and back, and this is no mean achievement.

At the recent manœuvres three squadrons—one bombing, one fighting, and one reconnaissance and spotting—took part, and it was considered by military attachés present that a degree of efficiency was shown equal to that to be found amongst many European countries to-day, and while the Brazilian Air Force is numerically stronger than that of Argentine, it is not, as yet, nearly so well trained.

The Naval Air Force is not so far advanced as that of the Army. Training is carried on at San Fernando, the seaplane station, but it would appear that the Army has a much greater pull on the purse strings of the nation than the Navy. The machines in use are nearly all Curtiss flying boats, but there are also a few French machines.

Buenos Aires reminds me very much of Pekin. The latter city is full of people trying to negotiate loans to the Chinese Government, while the former is full of people wanting to secure air concessions from the Government. The great similarity between the two is that neither succeed in their ambition. The reason for this negative result in both cases can be summed up in the two words "insufficient Bukshieh."

The British, French and Italians seem to be anxious to start freight, passenger and mail services to various parts of the country, provided that they are given the exclusive right to exploit their chosen route, but the Government does not appear willing to grant such rights.

Major Kingsley, an ex-R.A.F. officer, arrived in the country in 1919 and formed a company called the Sociedad Rio Platense de Aviacón. This company has operated for the last two years a successful cross-river service between Buenos Aires and Montevideo carrying mails and passengers. The service has only been worked during the summer months, the rest of the time being taken up with joy-rides and the training of pilots, and the company possesses an excellent 'drome at S. Isidro. Last season it was found that the distance from the town to the aerodrome, some 40 minutes by electric car or an hour and a quarter by motor car over what are termed roads, was often too much for a prospective passenger to face. The same time was lost at the Montevideo end.

To remedy this, Major Kingsley visited England during the winter (our summer) and purchased a number of seaplanes, so that in future the service will start from the North Basin, Buenos Aires, and finish in the Harbour at Montevideo, and *vice versa*. This means that the journey will be done in one hour and thirty minutes from hotel to hotel as against two hours and twenty-five minutes —a very considerable saving.

This new service should be of great commercial utility. The actual flying time should not exceed 65 minutes, and, always provided that the fares charged are not too high, the line will be patronised and should become a paying proposition.

Another source of revenue to this company is the private chartering of 'planes by rich estancieros to take them back from the capital to their estancias. By train such a journey often takes 24 hours, after which there may be a four or five hours' ride on horseback. By 'plane the whole distance can be done in four or five hours, and the question of a landing ground, as a rule, presents no difficulty owing to the general flatness of the country.

Altogether, the Rio Platense Co., since its foundation, has carried nearly 15,000 passengers and flown over 400,000 kilometres—a very creditable performance.

Another company started by the Italian constructor Caproni called the Italo-Argentine Aerobus Co. "Caproni" intends opening a service between Buenos

Aires and Montevideo. It is alleged that they are to use giant Capronis carrying 23 passengers and 3½ tons of cargo, but I think that this is doubtful.

The German-Spanish scheme for a Zeppelin line from Seville to Buenos Aires is beginning to take shape. The service is to be maintained by two dirigibles having 135,000 cubic metres' capacity, measuring 250 metres long and 34 metres in diameter. They are to have accommodation for 40 passengers and eleven tons of cargo. The duration of the voyage is to be 3½ days westwards and four days eastward, and the fare will be ptas. 6,000 or £200. Air ports are in course of contruction at the two termini and include hangars 300 metres long and 50 metres high. Both ports are well equipped with shops for undertaking repairs, and will also have wireless.

Capt. René Fonck, who paid a visit to the Argentine after Brazil, outlined a scheme for an aeroplane service from Paris to Buenos Aires. A committee of influential people was formed to study the best means of carrying it out, but that is as far as it has got, and probably as far as it ever will get. But the idea served the purpose for which it was intended excellently well, and that was to draw the attention of the Government and the people to the products of the French aircraft constructor.

I could tell you a great deal more about the Argentine, but time presses, and I think enough has been said to show that there is a great future there for aviation.

Before passing on to Chili, I should just like to show you what the Andes look like, so as to give you some idea what pilots had to face in attempting to fly over them.

Chili

Chili, with an area of 307,774 square miles and a population of some 4,500,000, has the distinction of having the only Air Force in South America which can be said to be modelled solely on British lines and using only British material.

The Naval Service, whose temporary bases are at Valparaiso and Quinteros, has been trained under Lieut.-Col. J. L. Travers, late R.A.F., with two British mechanics. The material consists of three Avros, four Shorts and two Sopwith seaplanes, also two Supermarine flying boats Channel type Mark II. fitted Siddeley "Puma" engine.

The Military Service has its headquarters at the aerodrome "Lo Espejo," near Santiago, while the Military Aviation School is at "El Bocque," which is next to "Lo Espejo." The school is housed in a fine large building, and is well equipped to teach the latest improvements invented for safe flying, as well as the usual military routine, including directional wireless and wireless telephony.

On the aerodrome are hangars built of reinforced concrete capable of holding ten or twelve machines of the Avro or Bristol type, and there is also an observatory and meteorological office.

The material consists of ten Avros, eight S.E.5A, eight Bristol monoplanes and twenty D.H.9 fitted with Siddeley "Pumas." They also have two Italian Svas, which, I understand, were gifted to the nation by Italians resident in the country. There is also a well-equipped repair shop employing some twenty-five mechanics.

All the afore-mentioned British machines were presented to Chili by Great Britain in part payment for the use during the war of the Chilian battleship "Latorre," named by us during the war the "Canada."

The very highest credit is due to Major Scott, late R.A.F., head of the British Mission to Chile 1920/21, who created and organised throughout the Chilian

Military Air Service, and this in spite of all kinds of political and diplomatic intrigue that was endeavouring to hinder the realisation of his task.

With thirteen Avros Major Scott trained 74 pilots and handed back thirteen Avros intact at the end of his contract. This, I think, is a wonderful performance, and one worthy of the highest traditions of the R.A.F.

The most outstanding flight made by a Chilian aviator was that of Capt. Aracena, the present Director of Aviation, who, accompanied by a British mechanic, flew on a D.H.9 with " Puma " engine from Santiago to Rio de Janeiro *via* Mendoza, Buenos Aires, Montevideo, Porto Alegre, etc.—a distance of 1,850 miles. This was in the spring (our autumn) of last year.

As regards commercial aviation, this does not exist at present. The principal difficulty in the way of establishing air routes in Chili is its configuration, which renders forced landings extremely hazardous, and might exclude the use of the aeroplane except for the Valparaiso-Santiago route.

A service between Valvidia on the 40th degree of latitude to Iquique on the 20th, with calls at Talcahuano, Valparaiso, Coquimbo and Antofagasta, has been mooted by people representing British and French interests using flying boats. The difficulty, however, is that, with the exception of Valparaiso and Talcahuano, the ports mentioned have no harbours, and the almost perpetual heavy swell experienced along the West Coast would make the landing at the different ports somewhat perilous.

Such a service, however, if it could be worked, would be an inestimable boon to the trade of the country, as at the present time the communications for mail and passengers are slow and erratic.

Peru

Peru, which has an area of 439,014 square miles and an estimated population of 5,000,000, possesses the nucleus of an efficient Air Force, under Comandante Juan Leguia, son of the President, who served with the British in the 7th Squadron R.N.A.S. during the Great War and won the D.F.C. The Naval Service has been trained by Capt. W. Simon of the U.S. Navy, and use mainly Curtiss flying boats.

The Military Service, under the control of Comandante O'Connor, a Peruvian of Irish descent, use British, French and Italian machines. It is not so efficient as the naval side, but in the summer of last year Comandante Leguia visited this country and made considerable purchases of material, securing also the services of Capt. Marsden, late R.A.F., to act as Chief Instructor, so that in the near future this service should become quite useful.

In 1919 the French sent out a mission, but in January, 1920, the head of this crashed and was killed, and this took away a great deal from their prestige. The Italian firm of Ansaldo had a mission here, and succeeded in getting two of their machines purchased by public subscription and presented to the nation.

The principal aerodromes are at Lima and Arequipa, and the repair shops are also in charge of a Britisher, Mr. Thurmer.

From the foregoing it will be seen that we have succeeded in ousting both the French and Italians, and have now got complete control of the Military Wing.

Turning now to civil aviation, there is one commercial aviation company, The Compania Nacional Aeronautica, Lima, which was formed in July, 1920, with American capital, and they are agents of the Curtiss Company. They started a service between Callao and Lima, but this had to be abandoned owing to lack of support, the reason being that there is an excellent tramway service between the two towns, taking only 25 minutes.

A mail service along the coast has been mooted, but nothing has so far materialised, due to lack of capital, and also on account of the heavy Pacific swell, already mentioned, making landing difficult.

In considering possible air routes, apart from the coastal one, the most important that immediately strikes one is that of linking up the Pacific with the inland port of Iquitos—2,175 miles up the Amazon from the Atlantic coast and 630 from the Pacific.

In 1918 Squadron Commander Dyott made the extremely hazardous journey from Pacasmayo to Iquitos to make an air route reconnaissance of the country from the coast to the latter town. The four possible routes were as follow:—

1. The Pichis trail from Lima *via* Oroya and thence to Iquitos.—Flying distance, 750 miles; present time, 32 days; flying time, 9½ hours.

2. Trujillo *via* Soledad and Parcoy, thence by the Huallaga river to Iquitos.—Flying distance, 590 miles; present time, 40 days; flying time, 7½ hours.

3. Pacasmayo, Chachapoyas, Balza Puerto and the Huallaga river to Iquitos.—Flying distance, 690 miles; present time, 64 days; flying time, 8½ hours.

4. Paita or Chiclayo to Bellavista, thence through the Pongo de Manseriche to Iquitos.—Flying distance, 630 miles; present time, 92 days; flying time, 8 hours.

Of these, the fourth would appear the easiest on account of the lower height of the Andes, at this point some 8,000ft., and the possibility of utilising the Rio Maranon for landing in case of necessity.

In the latter part of last year an American aviator named Faussett practically accomplished this flight, using route No. 4 as suggested by Dyott.

He left Chiclayo and flew 436 miles non-stop to within 60 miles of his destination, being forced to land in a violent storm at the point where the Rio Tigre joins the Maranon. He accomplished this remarkable flight on a Curtiss-Oriole with an 80 h.p. Curtiss engine, taking only six hours.

The difficulty in establishing such a route would, of course, be the ground work. Supplies and landing places, whether on land or water, would require to be established about every 200 miles, those on the east of the Andes being supplied from the Atlantic coast, and those on the west from the Pacific. Amphibious machines would be required, and the capital necessary about £250,000, as against £9,000,000 for building a railway.

The benefits of such a service are obvious, as it would bring this important area within 12 hours of the Pacific coast instead of 32 days as at present.

Colombia

I did not visit Colombia, but in order to make this paper as complete as possible, with your permission I will give a few details of the aerial activities in that country.

Naval or military aviation cannot be said to exist as yet, the activities in this connection being confined to a school for training pilots with French machines and French instructors.

The lack of the third arm, however, is amply counterbalanced by the wonderful progress that has been made in commercial aviation, both for the carrying of mails and passengers.

No other country in South America, and few in Europe, possesses such a complete system of air mails as does Colombia, and this is mainly due to the lack

of competition from other means of transport and the eminent suitability of the configuration of the country for aerial communication. The advent of the aeroplane and flying boat has been instrumental in solving a problem which seems almost insoluble by other means.

Before aerial transport was established the sole artery of communication with the interior was the Magdalena River, which is navigable for some 600 miles, as far as La Dorada. The shifting sands and shallow draft, however, made the duration of such a journey a matter of conjecture, and mail matter from this country often took as much as five and six weeks to get to the capital, Santa Fé de Bogotá. With the introduction of the air mail a letter takes less than three weeks, so that it is possible to get a reply to a letter in the same time that it previously took that letter to arrive at its destination.

The mail services are as follow :—

Barranquilla to Girardot.—This is a bi-weekly service leaving Barranquilla every Tuesday and Friday and arriving at Girardot the same day, a distance of some 350 miles, with stops at Monpox, Barranca, Bermeja, Puerto Berrio and Honda for the delivery of mail. From Puerto Berrio, the port on the Magdalena for Medellin, the mail is taken by special messenger to the latter town, and the same is the case at Honda to Manizales, and at Girardot for Ibagué, Bogotá and Tunja.

Mail forwarded by air arrives at Medellin, Ibagué and Bogotá on Wednesdays and Saturdays, and at Manizales, Neiva and Tunja on Thursdays and Sundays. Letters addressed to other cities in the interior of the Republic are landed at the river port nearest to the National Post Office of the district in which the town is situated.

Girardot—Barranquilla.—This service is the same as the foregoing, only reversed, the departure being on Wednesdays and Saturdays. The Wednesday service makes connection with the Clyde Line steamers sailing on Fridays from Puerto Colombia to New York. Mail from Bogotá to New York takes fourteen days. It also connects with Elders and Fyffes' steamers leaving on Thursdays and Saturdays from Santa Maria for Bristol, mail taking by this route twenty days from Bogotá to London.

Barranquilla and Cartagena.—This service flies every Monday, returning to Barranquilla the same day in time to make connection with the Tuesday Barranquilla and Girardot service.

Barranquilla and Santa Maria.—This service is the link between the Barranquilla and Girardot line and Elders' and Fyffes' steamers. The 'planes leave Barranquilla every Thursday and return the same day to connect up with the Friday Barranquilla and Girardot service.

These are all the services actually working at the moment, but they represent some 1,250 miles, which makes our London-Paris seem rather a weak effort in comparison.

The charges for mail are rather high, being 1s. 2½d. per ½oz., but the saving in time, as I have tried to show, is enormous.

The unfortunate part of all these services is that they are run by a German company. The Colombian-German Aerial Transport Company has a contract with the Government to carry the mails for five years, being subsidised to the extent of $100 or £20 per trip from Barranquilla to ports on the Magdalena River. During the three months ending October, this Company made 307 flights, totalling 57,640 kilometres, carrying 303 passengers and 29,280 kilos of mails and freight. All the machines used are German, namely, Junker monoplanes.

For a country with only five millions of population this is a wonderful record, and rather makes one wonder why the people of this country, the hub of civilisation, do not patronise our continental services more.

In conclusion, I would say that great opportunities await the aircraft constructor, the pilot and the capitalist in South America. The continent is developing fast, and the means of transport essential to that development are slow. The people, unhandicapped by tradition, take to aviation with probably better grace than did our forefathers to the railway. The meteorological conditions are far better than those found in Europe.

With a return of general trade to something like its pre-war prosperity, South America should prove a large and steadily increasing buyer of aircraft, but it will want the very latest in design and construction, not surplus war stock.

REVIEWS

Etude Sur le Ballon Captif et les Aeronefs Marins

Par le Commandant Charles Lafon. Paris: Gauthier-Villars et Cie., Quai des Grands-Augustins, 55. 1922.

The subject matter of this book divides naturally into two parts. The first four chapters deal with the modern French kite-balloon and the remaining three are devoted to the mathematical study of aeronautical tactics with an application of it to surface ships. On neither subject has a great deal been written; indeed, in the case of the balloon, the author has practically a virgin field, as practically nothing of value exists outside the official manuals which have been written for the various national air services. More frequently than not the author of a new technical treatise needs to commence his book with a schedule of reasons, most of them more or less artificial, in justification of adding still further to the troubles of a world already grossly overloaded with treatises on the subject of his choice. Monsieur le Commandant Lafon does not do this; and rightly so, for any apology of this sort would be out of place, for his book, whilst not breaking a great deal of new ground, forms a very real and useful contribution to the literature of branches of aeronautics which much need written records. The development of the kite-balloon is the least spectacular of modern aeronautical developments, and the uses to which a type of aircraft which has no motive power of its own can be put are obviously limited. In its own sphere, however, the captive balloon did excellent service during the war at a cost in men and material comparing very favourably with that of other forms of aircraft. Although at the present time interest in balloons has dwindled to very small proportions, there is no reason for considering them abandoned permanently in favour of more recent developments. In particular, war requirements are likely to involve the use of captive balloons for many years to come for dealing with the problems which come within their particular sphere to the exclusion of other classes of craft, either lighter or heavier-than-air. The present book is to be welcomed, therefore, as putting on record the results of a good deal of research and experience on the subject. The combination in one work of two, at best, only loosely related subjects is due to the fact that the book is a presentation of the lectures given by the author before the commissioned and non-commissioned officers and cadets at the aviation stations at Corfu and Mudros during the war. In writing his book he has kept the subject matter within the limits of his lectures, whilst amplifying the detail of his treatment in various places, particularly in the mathematical treatment of various problems.

In Chapter I. a general account is given of the handling and working of naval kite-balloons, as practised at Corfu and Mudros. The details are essentially

of a practical nature. Descriptions are given of how to let up a balloon from the deck of a vessel, how to haul down under various conditions of weather, etc., the methods of transferring between ship and shore, arrangements of balloon stations, and so on. The main general features of meteorology as they affect the handling of naval balloons find a place here, as do also a description (which would be clearer if illustrated by a drawing) of the rigging of an R-type Caquot balloon and the balloon drill developed by the author and used by the French naval balloon units in the Near East. The chapter closes with a very condensed account of the silicol method of generating hydrogen and of the process employed for compressing the gas into tubes. A good deal of the matter in this chapter is of the sort which may be found in general instructional manuals, but some of it is in a more abridged form.

The next three chapters are concerned with dynamical problems related to the kite-balloon. Chapter II. deals very fully with the form of the curves taken up by the cable with and without a wind, equations giving the form of the cable and the relative tensions in it being arrived at by an extension of the well-known principles used in determining the equation to the catenary and other forms of suspension cable. The subject of dynamic lift is also treated in this chapter, and one cannot but remark on the apparent indifference to aerodynamic data which characterises the French treatment of balloon problems in general. Although it may legitimately be considered that the aerodynamic forces acting on a balloon form a relatively large proportion of the whole, especially when the balloon is being towed at high speeds, no reference is given in the book to any wind channel or other measurements of wind forces, but the author is content to state that the dynamic lift of a 150 cubic metre Caquot balloon may be given with sufficient approximation by the formula

$$0.5\ V^2 \sin i$$

i being the angle of pitch of the balloon and V the relative air speed (metric units). Some attention is devoted to the case of a balloon carrying an independent auxiliary cable, a matter which is of minor importance, at any rate in British practice, at the present day by reason of the development of telephone-cored cables, which render independent telephone cables unnecessary.

There appears to be a certain confusion of terms in the title to Chapter III., "Analytical Investigation of the Equilibrium of the Elongated Captive Balloon." The author actually discusses the questions of stability in pitch and yaw, his treatment of the relatively simple problems of equilibrium (as distinguished from stability) having been considered in the previous chapter. His treatment of stability differs from that developed in this country by Bairstow and others as an application of the Bryan-Bairstow method. The author considers separately the oscillations set up by small displacements in pitch and yaw, a treatment which is incomplete. Admitting the limitations of this method, there is something to be said in favour of its practical value. In attempting to apply the complete theory of stability we soon come up against factors which, at any rate in the present state of our knowledge, it is not possible to evaluate or even to hazard a close guess at their relative effects on the results. On the other hand, the more limited mathematical results arrived at by the analysis given in the book have enabled a number of practical deductions as to fin area, etc., to be arrived at, which have undoubtedly contributed largely to the evolution of a practicable balloon.

Chapter IV., a short one of five pages, deals with an important practical problem, namely, the determination of the stresses set up in the cable when letting up or hauling down a balloon in a wind. The analysis leads to the conclusion that under certain circumstances of hauling down rapidly a maximum tension approaching fairly close to double the static value may be set up in the cable, a matter of considerable importance when the low factors of safety that

have to be used in balloon work are taken into account. This chapter completes the author's notes on balloons.

A new line of thought is started in Chapter V. in which the author applies mathematical methods to some problems of aerial tactics. He deals almost exclusively with problems arising out of aircraft patrol work at sea. He begins by evolving equations to paths which an observing aircraft must follow in order to keep at a constant distance from a (slower) surface ship or squadron with which it is keeping in touch, and follows this up by a series of problems of a similar nature. The material of this chapter formed the subject of a communication to the French Academy of Sciences in 1922 by Professor Koenigs, of the Sorbonne. The author claims that the working out and plotting of such paths would be of advantage in enabling chasing craft to keep in closer touch with their quarry. For naval and air officers with sufficient capacity for and interest in mathematics to enable them to follow out the complete theory and apply it to the various cases that may arise in practice, it is probable that a study of the contents of this chapter would be of considerable theoretical advantage, but it seems scarcely that its practical value goes beyond this.

Chapter VI. is of a similar character to the preceding one, but deals with the kinetics of such aeroplane evolutions as spiralling, pancaking, looping, etc., and the author determines by mathematical reasoning the decelerations and changes of motion which take place in various cases. His results certainly bring out how and under what circumstances these evolutions can become dangerous. In the following chapter he applies the same principles to evolutions of ships at sea.

The book consists rather of a series of essays on problems of applied mechanics relating to naval aeronautics than of the chapters of a connected treatise. This applies particularly to the last part of the book. The first four chapters have a much closer connection of interest; but, excepting the first one, which deals with the practical field and sea work of handling and using kite-balloons, they deal mainly with a special phase of the subject only. Throughout the volume it is evident that the author's talent for applying mathematics to the problems met with in the practical work of his profession has been the main cause from which the treatise originated. And this gives the book its distinctive character, not as an aeronautical text-book, but rather as a collection of mathematical solutions of problems arising out of the use of kite-balloons and other aircraft at sea. Anyone turning to the book in the expectation of learning anything of the details of kite-balloon construction and design must inevitably be disappointed as it is quite devoid of such descriptive matter either written or in the form of diagrams. Whilst of very little use to anyone who has not some fair acquaintance with the subject, to the designer who wishes to look at his problems from a scientific standpoint and to eliminate rule-of-thumb from his work as far as possible, the book affords subject matter for much profitable thought. The chapters dealing with tactical kinetics and dynamical problems of aeroplane evolutions fall into a similar category; they are for the individual who has already a good general grasp of his subject and who can widen his knowledge and equip himself the better for considering new problems of a similar nature to those discussed in the book.

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